University of Alberta

SEXUAL MATURATION OF FEMALE TURKEYS AS AFFECTED BY STRAIN AND PHOTOSTIMULATION PROGRAM

by

VALERIE MELNYCHUK ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled SEXUAL MATURATION OF FEMALE TURKEYS AS AFFECTED BY STRAIN AND PHOTOSTIMULATION PROGRAM by VALERIE MELNYCHUK in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in ANIMAL SCIENCE.

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ABSTRACT

Two studies were conducted to investigate the effects of strain or photostimulation program on the reproductive development of female turkeys. In trial I male line and female line birds were killed for assessment of reproductive organ morphology at 3 d intervals following photostimulation and at first egg (sexual maturity). The age of sexual maturity was similar for both lines. Male line birds were 3 to 4 kg heavier than female line hens, while having similar abdominal fatpad weights. Female line birds had significantly more carcass lipid as a percentage of BW than male line birds (24.76% *vs.* 22.79%, respectively). Female line birds had significantly higher plasma estradiol-17β concentrations than male line birds (86.84pg/ml *vs.* 68.31 pg/ml). Male line birds had significantly more large follicles with a greater proportion in a triple or greater hierarchical arrangement. On average, male line birds had 3.0 unreconciled post-ovulatory follicles at sexual maturity, while the female line had 1.6. These follicles were presumably lost through internal ovulations as evidenced by a correlation coefficient of .4386. The growing oviduct of the female line reached its mature weight 3 d earlier than the ovary did. The growing ovary and oviduct of the male line reached their mature weights on the same day. The development of the male line ovary is accelerated relative to the oviduct, resulting in lost ovulations early in lay.

In trial II female commercial turkeys were used to investigate the effects of a gradual lighting program on onset of sexual maturity, reproductive development and subsequent egg production. Under a conventional (CON) lighting program birds were photostimulated from 6L:18D to 14L:10D at 29 wk. The alternate (ALT) lighting program involved weekly .5 h decreases in daylength to 17 wk followed by weekly .5 h increases in daylength beginning at 20 wk. Birds were killed at 3 d intervals to assess reproductive development, and at sexual maturity. A final group of birds were

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maintained for egg production records. The growing oviduct of the CON treatment reached its mature weight 5 d earlier than the ovary did. The growing oviduct of the ALT reached its mature weight 4 d after the ovary. Ovarian development of the ALT treatment was accelerated 10 d ahead of that of the CON treatment. The number of unreconciled ovulations as evidenced by post-ovulatory follicles at first oviposition were not different between treatments (1.2 ALT; 1.6 CON). ALT birds reached sexual maturity at a significantly younger age (220 d *vs.* 224 d) and BW (11.18 kg *vs.* 11.88 kg) than CON birds. The number of large follicles was not different between the two treatments (12.9 ALT; 14.3 CON (P=.092)). First egg weights were significantly smaller (70.6 g ALT; 77.2 g CON) for the ALT treatment which also had a higher incidence of small eggs for the first 4 wk of production (3.31% ALT; .82% CON). Total egg production and settable egg production were not significantly different between treatments.

I. INTRODUCTION

Modern strains of turkeys (*Meleagris gallapavo)* have descended from domesticated birds that existed in North America between 200 B.C. and A.D. 700 (Crawford,1990). Breeding turkeys for meat production dates back to the early 1500's when turkeys (*Meleagris gallapavo)* were first introduced to Europe from Mexico by Spanish Conquistadors. These European stocks were reintroduced to North America in the 1600's as settlement proceeded. Matings between wild turkey toms (*Meleagris gallapavo silvestris)* and the smaller domestic hens resulted in progeny that were larger and more vigorous than either parent. This gave rise to the commercial bronze bird that replaced the Mexican black in North America and Europe. The modern broad-breasted turkey has evolved from these crossbred ancestors through genetic selection (Crawford, 1990).

Since the 1940's domestic turkeys have changed dramatically as compared to their relatives, the wild turkey. These changes are the result of much research as well as the application of genetic selection principles. Over the past 50 years, very large populations have been involved in selection programs of breeder companies and thus fairly accurate estimates of heritabilities and genetic correlations are available (Marks, 1990). Generally, reproductive traits demonstrate low heritabilities whereas the heritability of growth rates is moderately high (Marks, 1990). Arthur and Abplanalp (1975) reported that the heritability for increased BW of females as averaged over 17 studies to be .41. Nestor (1984) reported the heritability for the sixteenth generation of females at 16 wk BW to be .24. Reproductive traits such as egg number were reported to be much less heritable with an average heritability of .22 (Arthur and Abplanalp, 1975). Upon summarizing data of twelve studies spanning

almost three decades, Kinney (1969) also reported the average heritability of egg production to be .22 Although, the heritabilities of reproductive traits are relatively low, they are important traits to breeder companies and thus warrant selection effort.

As well as heritabilities, genetic correlations have also been important tools for breeder companies. Positive correlations between traits allow for some traits to be selected for indirectly, whereas negative correlations between traits make the selection process more complicated For example, egg number may be indirectly selected for while concentrating on fertility and/or hatchability, as these three traits are all positively correlated (Nestor, 1972). However, the high heritability of growth and carcass traits complicate selection for egg production as growth and reproductive traits are negatively correlated (Nestor, 1984; Nestor and Bacon, 1986) This however, does not necessarily mean that one trait must be sacrificed for another. Improvements in egg production in conjunction with improvements in carcass traits demonstrate this.

Turkey breeding may be defined as the utilization of science for the improvement of economically important traits which may result in the development of many turkey strains. Economically important traits depend largely on consumer demand. Presently, the largest single product of turkeys is meat production, more specifically breast meat (Richardson, 1989). Since meat yield is of such value to the industry, major emphasis has been and continues to be placed on growth characteristics such as meat (breast) yield, growth rate, and feed conversion efficiency. However, also important to breeder companies is egg production and ultimately viable poult production.

As with chickens, modern strains of turkeys can be divided into two types. Male line

birds have been selected primarily for growth and carcass traits. Performance goals for growth rate are more than double those reported in a survey by Marsden and Knox in 1937 (Marks, 1990). Although female line birds result from selection primarily emphasizing reproductive traits, production of viable poults has been compromised as BW of these strains continued to increase over the last four decades (Nestor and Bacon, 1986). Management of these very different strains for viable poult production is a complex equation with many factors to consider, including genetics, nutrition, environment, disease and lighting program which each affect reproductive potential of a hen.

Growth selected lines characteristically possess many more ovarian follicles as compared to egg-type birds (Nestor, 1971) This abundance of ova contributes to the reproductive loss of turkeys and broiler breeders. Studies comparing heavy BW lines of turkeys to lower BW lines have reported a greater number of ovarian follicles for the heavy weight birds (Nestor *et al.*, 1970,1981; Hocking, 1992). Early photostimulation can further exacerbate the problem of excess ova (Hocking *et al.*, 1988). Numerous follicles are often arranged in multiple hierarchies in which more than one follicle occupies the same position in the hierarchy. With multiple hierarchies a single LH surge can result in multiple ovulations (Yu *et al.*, 1992). Possible consequences of this are internal ovulation or poor shell calcification of more than one follicle occupying the shell gland (Hocking *et al.*, 1992; Yu *et al.*, 1992). Renema *et al.* (1995) identified "unreconciled" ovulations early in lay as another source of reproductive loss. Male line hens killed at sexual maturity (first oviposition) had ovulated on average 4.9 times as evidenced by unreconciled post ovulatory follicles (POF). The fate of these follicles is unclear but they may represent internal ovulations.

Compromised egg production due to increased follicle numbers and poor reproductive function result in part from genetic selection for growth and carcass traits of modern turkey hens (Nestor, 1971). A clearer understanding of the reproductive development of various lines of turkeys may help to develop management strategies to alleviate or lessen some of the reproductive problems of today's turkeys. The amount and quality of light that turkeys are exposed to during different developmental periods can have a profound affect on reproductive development and subsequent egg production. Currently, conventional programs normally involve photostimulation of physically mature hens at 28 to 32 wk of age. With 15 to 16 h of light, the onset of egg production usually begins within 3 to 4 wk. Studies dating back to the 1960's investigated the use of gradual lighting programs that mimicked the naturally occurring daylength (McCartney *et al.*, 1961; Marsden *et al.*, 1962). Generally, these lighting programs were not found to be of much benefit as compared to the conventional programs. Since these studies, bird genetics and management strategies have changed considerably. The benefits of gradual lighting programs should be reinvestigated under current conditions.

Ovary Morphology and Follicular Growth

As adults, female chickens and turkeys possess only one functional ovary although two ovaries exist during early embryonic life (Etches, 1995). As the embryo develops the right ovary regresses while the left ovary remains. This remaining ovary is located in the cranial region of the abdomen, just anterior to the kidney (Gilbert and Wells, 1984). At this stage, the ovary is comprised of approximately 12,000 tiny white follicles (Gilbert, 1971) which are supported by a rich vasculature (King and McLelland, 1984). Much of the

knowledge regarding ovarian structure, function and growth has been obtained through extensive research with the domestic hen, however this information can generally be applied to the turkey.

Ovarian follicles range in size from an abundant supply of small white follicles to a hierarchy of large yellow yolky follicles. The ovary of a chicken (egg-type hen) normally contains 6-8 (Gilbert, 1971) large yellow follicles (<10 cm diameter), while a turkey in peak production may possess 9 to 18 large yellow follicles, depending on strain (Sharp, 1989; Renema *et al.*, 1994). Robinson and Etches (1986) classified the small follicles as small white (SWF, 1 mm), large white (LWF, 2-3 mm), and small yellow (SYF, 5-10 mm). LYF develop from a pool of several thousand SWF that are recruited into the hierarchy of 10 to 20 LWF and 5 to 10 SYF (Robinson and Etches, 1986). Growth of the ovary is initially slow as white primordial yolk is deposited to the SWF until they reach the LWF stage. Upon reaching a diameter of (5-8 mm) the follicles enter the final stage of rapid growth (Sharp, 1989). This stage is characterized by rapid deposition of yellow yolk to form a hierarchy of large yellow follicles. The largest follicle (F1) of the hierarchy is ovulated when it reaches a diameter of about 40-45 mm (Sharp, 1989). The size of the follicle however, does not solely determine when it will be ovulated. Ovulation depends on the synchronization of follicular maturation within a specific period of time. The mechanisms involved in follicular recruitment are not clearly understood but selection of follicles destined to be ovulated occurs at the LW stage (Gilbert and Wells, 1984). Selection proceeds through a process of differential atresia and results in a hierarchal arrangement in LWF before entering the rapid yolk deposition stage. For a follicle to grow from 8 mm to an ovulable size takes 11 to 13 d (Bacon *et al.*, 1972;

Hocking *et al.*, 1988).

Under the influence of estrogen produced by the SWF the liver produces very low density lipoproteins (VLDL) which are transported to the developing follicles (Etches, 1995). Yolk is comprised of its major precursor, VLDL (65%), as well as vitellogenin and proteins (Etches, 1995) The application of these components to the oocyte is mediated by many surrounding cell layers. To facilitate the rapid deposition of yolk the perivitteline layer has many projections which extend into the underlying yolk to increase the surface area for receptor-mediated endocytosis (Etches, 1995). Surrounding this layer are the granulosa cells which act as filters and pass small particles taken up by the perivitteline layer. The yolk components are delivered to the developing ovum from the liver via blood vessels which cover the theca externa layer. The theca interna layer is between the outer thecal externa layer and the granulosa layer. Within the theca interna layer are many terminal capillaries from which yolk components are obtained (Moran, 1987). The many layers of granulosa cells of immature follicles subsequently become a monolayer in LYF. Theca and granulosa cells are responsible for the steriodegenic output of the ovary (Etches, 1995). Nearly the entire follicle is covered with a highly vascularized layer of connective tissue. Follicular rupture during ovulation occurs at the avascularized region around the midsection of the follicle called the stigma.

Follicular maturation

The involvement of the granulosa and theca layers in the development of the follicle extends beyond the acquisition of yolk. In addition to stimulating the liver to produce yolk precursors, steroid hormones of the thecal and granulosa layers as stimulate development of

the reproductive tract, calcium deposition in the medullary bone and comb growth (Etches, 1995). As the follicle matures the interactions of the thecal and granulosa layers change. Estrogens and androgens are the major products of biosynthesis of pregnenelone of the SWF and LWF (Robinson and Etches, 1986). As rapid yolk deposition begins the follicles acquire the ability to convert pregnenolone to progesterone. At the same time the thecal layer of the F_n to F_2 follicles lose the ability to produce estrogens and thus, androgens become the main product (Robinson and Etches, 1986). Ovulation of the F_1 follicle occurs in response to increasing levels of LH. Lutenizing hormone and progesterone interact in a positive feedback loop. As the F_1 is ovulated the next largest follicle takes it position in the hierarchy. Within a few hours in the F_1 position, the major steroid output of this follicle is progesterone. The thecal layer loses its ability to metabolize progesterone that is produced by the granulosa layer, to androgens and thus progesterone synthesis proceeds uninhibited (Robinson and Etches, 1986).

Oviduct morphology

The oviduct is the organ responsible for packaging the ovulated ovum into a hard shell egg. This process which takes 24 to 25 h in the chicken and 25 to 27 h in the turkey is accomplished by five distinct regions of the oviduct (Etches, 1995). The infundibulum is at the cranial end of the oviduct and resides in close proximity to the ovary. This funnel shaped region is thin and lightly muscularized, and is responsible for capturing the ovulated ovum. Sperm host glands are located in the infundibulum, thus fertilization also occurs here. The second and longest region is the magnum. Passage of the ovum through the magnum is

relatively quick. Within 2 to 3 h, albumen from secretory glands is deposited around the ovum. Following albumen deposition, two shell membranes are applied and water is imbibed, in the isthmus. The ovum spends approximately 1.5 h in the isthmus. From the isthmus the egg passes into the shell gland. Calcium carbonate is deposited into a proteinaceous matrix to form the shell. Shell deposition takes 18 to 24 h. Pigmentation is also added in this region. The final destination before oviposition is the vagina. Immediately prior to oviposition, cuticle is applied. Cuticle prevents bacterial contamination of the egg. The vagina opens to the cloaca and responsible for the muscular contractions that result in expulsion of the egg (oviposition).

PUBERTY

The onset of sexual maturity, puberty, is a process that occurs over a few weeks. Upon the attainment of age and BW thresholds, an increase in daylength will initiate a cascade of hormonal events (Bornstein *et al.*, 1984 and Brody *et al.*, 1984). However, even without photostimulation sexual development will eventually proceed (Etches, 1995). Gonadotrophin releasing hormone (GnRH), luteinizing hormone (LH), progesterone and estrogens interact in complex positive and negative feed back systems. Photostimulation stimulates the hypothalamus to release GnRH causing increases in plasma LH levels. Increased plasma LH from a base level of 1.5 ng/ml to a plateau of 6 ng/ml mark the first stage of sexual development (Wilson and Cunningham, 1980). Following this initial increase in plasma LH levels are many more stages of development. The second stage is marked by the start of ovarian and oviductal growth and an associated steady increase in the concentration of plasma

LH. Comb growth under the influence of estrogens also begins in chickens. Thus, the levels of LH and estrogen are rising at the same time. However, because estrogen exerts a negative feedback on the release of GnRH, it would be expected that LH secretions would decrease as estrogen secretions increase (Wilson and Cunningham, 1980). Since both hormones increase during early sexual development a decrease in the sensitivity of the hypothalamus to estrogen must also occur (Wilson and Sharp, 1975). Progesterone levels do not rise at this time. The final stage of sexual maturity is marked by the first oviposition.

The prepubertal increase in LH is followed by a decrease in plasma LH levels 3 to 4 wk prior to ovulation (Wilson and Sharp, 1975). This decrease in LH levels forms the prepubertal peak. As a result of this fall the base-line level of LH in laying hens is significantly lower than in immature pullets with undeveloped ovaries (Wilson and Sharp, 1975). This decrease in plasma LH is due to a decreased sensitivity of the pituitary to GnRH (Wilson and Sharp, 1975). Ovarian steroids cause this negative feedback of LH release (Etches, 1990). Once the differentiation of the 1-4 mm diameter follicles occurs, LH release reaches the peak (Wilson and Sharp, 1975). As the follicle enlarges, it produces increasing amounts of estrogen. After the follicle becomes the second largest follicle (F2) in the hierarchy, it loses the ability to convert progesterone to estrogens and androgens (Robinson and Etches, 1986). Thus, plasma progesterone levels increases, ultimately leading to ovulation.

Growth of the ovary occurs in two phases. The first phase involves differentiation of SWF (Etches, 1995). There is little yolk deposition associated with this enlargement of the stroma. The final phase of ovarian development occurs very rapidly, over a period of 4 to 11 d (Bacon and Cherms, 1968) when yellow yolk is deposited to a relatively small number of

follicles to form a follicular hierarchy. This rapid increase in yolk deposition results in a corresponding rapid increase in ovarian weight.

Prerequisites for sexual maturity

The age of onset of sexual maturity as induced by photostimulation varies with genotype and is likely to be dependent on BW and body composition. Reproductive development will proceed in birds maintained in complete darkness throughout their lives (King, 1962). Photostimulation acts to modify the size and timing of nueroendocrine events associated with sexual maturity. The photosexual response of a bird to an increase in daylength depends upon the age at which it is given (Etches, 1995). These responses are not linearly related to daylength. A change in photoperiod in the range of 8 h to 16 h have a greater effect than changes outside this range (Morris, 1967).

It has been reported that *ad libitum-fed* broiler breeders reached sexual maturity earlier than lighter BW, feed restricted birds. This difference in age of sexual maturity was because *ad libitum* birds attained the prerequisite body mass and body composition sooner than restricted birds (Brody, *et al.*, 1980; Hocking *et al.*, 1989; Yu *et al.*, 1992). Kennedy and Mitra (1963) reported that minimum BW for the onset of sexual maturity is controlled by the absolute rate of energy intake relative to BW. In a study by Dunn *et al.* (1990) birds fed a diet diluted with corn oil had higher carcass fat contents. In response to photostimulation the corn oil-fed birds began ovarian development at 7 wk compared to 15 wk in *ad libitum-fed* birds. The precise age, BW and body composition requirement for the onset of sexual maturity are not well defined. It is likely that these factors are not exclusive

and that together they have an influence on the attainment of sexual maturity.

OVULATORY CYCLE

Domestic fowl hens lay eggs in sequences of 1 to 300 eggs (Robinson, 1990). High rates of egg production are a reflection of long sequences with short pause periods (Robinson, 1990). A sequence is a series of eggs laid on successive days while no eggs are laid on a pause day. Oviposition of chickens is limited to 8 or 11 h in a solar day for chickens and turkeys, respectively (Sharp, 1989). With conventional lighting programs, eggs are laid a few h after the dawn signal (Bixler and Ringer, 1968). Each egg of a sequence is laid later in the day then than the previous egg. Oviposition commences earlier in the day for long sequences and later for short sequences (Woodard *et al.*, 1963). Chickens and turkeys utilize cues from the photoperiod to "set their clocks." Thus, adjustments to the dawn/dusk signals will affect the daily distribution of egg laying within a day (Bixler and Ringer, 1968).

The restriction of oviposition to an 8 or 11 h period of the day is determined by a circadian rhythm (Etches, 1995). This neuroendocrine control mechanism facilitates the preovulatory hormonal cascade and ultimately results in ovulation within an equivalent 8 to 11 h period in chickens and turkeys, respectively (Sharp, 1989). The precise physiological events governing this circadian rhythm have not been elucidated. This period is referred to as the open period for LH release.

A mature follicle will respond to an LH increase, during the open period, by ovulating. No increases in progesterone or LH occur on pause days (Sharp, 1989). The

preovulatory increases in LH and progesterone are the results of a positive feedback loop (Sharp, 1980; Wilson and Cunningham, 1984). As the F_1 follicle matures it's production of progesterone increases (Etches, 1990). Progesterone stimulates a release of GnRH from the hypothalamus to the pituitary. Upon stimulation by GnRH the pituitary releases LH and follicle stimulating hormone (FSH). The progesterone production of the F_1 follicle increases further in response to an LH increase. The preovulatory levels of LH and progesterone increase until the build up is terminated by ovulation (Sharp *et al.*, 1981) The cascade of hormones begins 10 to12 h before ovulation. Plasma LH concentrations peak 6 to 8 h before ovulation, while progesterone levels peak 2 to 4 h prior to ovulation. The duration from the preovulatory LH peak and oviposition is approximately 36 h, under a 14 h daylength. A follicle resides in the oviduct 24-27 h (Etches, 1995).

Open period

The open period restricts LH and progesterone surges to 8 h per day, which thus restricts oviposition to an equivalent 8 h period (Etches *et al.*, 1984) The precise mechanism of the open period has not been elucidated, however it has all the characteristics of a circadian rhythm. Ahermeral lighting schedules (longer or shorter than a 24 h/d) can shift the timing of oviposition by changing the position of the photoschedule in a solar day. Without any environmental cues from the photoperiod, the open period will free run, resulting in ovipositions throughout the day and night. Under constant illumination, ovipositions will occur throughout a 24 h solar day. The timing of the open period is related to the transition from "lights on" to "lights off." Etches (1990) showed that as little as 1 h of darkness is

sufficient to synchronize the timing of LH release in most hens. This minimal exposure to dark does not alter the timing of ovulation as compared to that of hens exposed to a conventional photoperiod.

Follicular maturation

Eggs are laid in sequence as a result of follicular maturation interacting with the open period (Etches *et al.*, 1984). As the F_1 follicle ovulates, maturation of the next largest follicle in the hierarchy begins. The steroid output of the follicle changes from androgens to progesterone and the progesterone in turn stimulates a preovulatory surge of LH. Thus, ovulation of the F_1 follicle initiates maturation of the newly recruited follicle. High rates of lay are associated with rapid maturation of the follicle. Eggs at the end of a sequence are laid later in the day. A sequence is terminated when the F_1 follicle does not produce progesterone within the open period. Though follicular maturation will proceed, due to the limiting effects of the open period on LH secretion, ovulation is inhibited. The next sequence will commence at the beginning of the next open period with the initiation of both progesterone and LH secretion (Etches *et al.*, 1984).

PHOTOPERIOD

Extensive research has been devoted to explaining the effects of light on the avian reproductive and endocrine systems. The precise mechanisms of these effects are still to be determined. In birds, light is perceived through the eye and the skull, however, for the purposes of reproduction, light perception does not depend upon the eye (Etches, 1995). Research spanning the last five decades has demonstrated that light energy is transduced into

neural signals by rhodopsin in the hypothalamus (Etches, 1995). These nueral signals initiate the endocrine events involved in sexual maturation and egg production. Removal or lesioning of the hypothalamus prevents any endocrine responses when birds are exposed to light (Etches, 1995).

Photorefractoriness

An adult bird is considered as being photorefractory when it is unable to maintain gonadotrophin secretion during exposure to long daylengths. Turkey poults are hatched in a photorefractory state (Noll, 1989). Asmundson and Lloyd (1935) observed that birds hatched in December and January reached sexual maturity very slowly and had poor subsequent egg production even though they were fully grown when the daylength of summer began to increase. Marr *et al.*, (1956) were among the first to observe that egg production improved in hens in January when exposed to 8 h of light per day between 14 and16 wk. Many studies have since confirmed and elaborated these findings. Ogasawara *et al.* (1962) demonstrated that 3 wk of exposure to daylength of 6 h was the minimum requirement to dissipate photorefractoriness. Generally, most studies found that 3-6 wk of exposure to short daylengths of 6-8 h improved egg production by dissipating photorefractoriness (Noll, 1989).

Photorefractoriness is primarily due to an inhibition of the central nervous system to the synthesis and release of GnRH (Sharp, 1989). The gradual development of photorefractoriness reflects a progressive long day dependent development of inhibitory input of the central nervous system on neurons of the hypothalamus. Egg production decreases progressively as photorefractoriness develops due to a reduction of LYF (Hocking *et al.*, 1988) and a progressive decline in plasma progesterone concentrations (Mashaly *et al.*, 1976).

Lighting programs

It is well understood that photostimulation will initiate the onset of sexual maturity in turkeys. However, photostimulation is not a prerequisite to the onset of sexual maturity, rather it synchronizes the physiological and endocrine events that precede first oviposition (Etches, 1995). The timing of photostimulation and the manner in which it is employed affects sexual maturity and subsequent egg production. Increasing the daylength of a light restriction period of 3 wk or longer from 6 to 8 h stimulates egg production (Marsden *et al.*, 1962; Wilson *et al.*, 1962). However, to obtain maximum egg production birds should be photostimulated with 14-16 h of light (Marsden *et al.*, 1962; Ogasawara *et al.*, 1962). Studies have shown that photostimulating with more than 16 h of light does not improve egg production (Leighton and Shoffner, 1961; McCartney *et al.*, 1961; Ogasawara *et al.*, 1962).

Some studies have investigated effects of a gradually increasing photoperiod, designed to more closely mimic the changes in natural daylength. Egg production was not different between hens that had been photostimulated abruptly from 9 to 15 h or those exposed to weekly 2 h increases from 9 h (McCartney *et al.*, 1961). Marsden *et al.* (1962) found that the time interval to first egg was longer for birds photostimulated with 30 min/d increases in light as compared to birds photostimulated abruptly with 11, 13 or 15 h.

Since adult birds do eventually become photorefractory regardless of previous light restriction, some studies have attempted to improve persistency of production by gradually increasing the photoperiod throughout the production cycle. Lengthening the photoperiod by 15 min every 2 wk after peak production (3 wk) to 180 d of production did not improve egg production as compared to the control (14L:10D) (Bacon and Nestor, 1977). Similar

results were observed by Cherms (1982) and McCartney *et al.*, (1961) who increased the photoperiod from 14 to 15 h after 10 wk of production or increased the photoperiod by .5h/wk starting at 15 h and ending when the daylength reached 22 h.

Research Projects

Objectives

The purpose of this research was to characterize reproductive development of female turkeys. The effects of strain and photostimulation program on ovary and oviduct morphology, sexual maturity, and egg production were examined. Plasma lipid concentrations during the onset of sexual maturity and carcass composition at sexual maturity were also investigated.

Project Descriptions

Project 1. This project was designed to characterize reproductive development on a chronological basis. Male line and female line birds were used to investigate the differences of genotype.

Project 2. A conventional photostimulation program and a gradual photostimulation program were used to investigate differences in reproductive development, sexual maturity and egg production. The effectiveness of a gradual photostimulation program for commercial hens was determined.

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II. Sexual Maturation in Male Line and Female Line Turkey Hens

Abstract

A study was conducted comparing the ovary and oviduct development after photostimulation in female line and male line turkeys. Birds were killed for assessment of reproductive organ morphology at 3 d intervals following photostimulation and at first egg (sexual maturity). The age of sexual maturity was similar for both lines. Male line birds were 3 to 4 kg heavier than female line hens, while having similar abdominal fat pad weights. Female line birds had significantly more carcass lipid as a percentage of BW than male line birds (24.76% *vs.* 22.79%, respectively). Female line birds had significantly higher plasma estradiol-17β concentrations than male line birds (86.84 pg/ml *vs.* 68.31 pg/ml). Male line birds had significantly more large follicles with a greater proportion in a triple or greater hierarchical arrangement. On average, male line birds had 3.0 unreconciled post ovulatory follicles at sexual maturity, while the female line had only 1.6. These follicles were presumably lost through internal ovulations as evidenced by a correlation coefficient of .44. The developing oviduct of the female line birds reached its mature weight 3 d earlier than the ovary did. The developing ovary and oviduct of the male line reached their mature weights on the same day. The development of the male line ovary is accelerated relative to that of the ovary, resulting in lost ovulations early in lay.

Introduction

The period of time between photostimulation and sexual maturity is a critical one in that bird management during this period will potentially affect subsequent egg production.

The ovary and oviduct undergo many stages of development as sexual maturation progresses (Wilson and Sharp, 1975). The first stage is initiated by photostimulation and lacks any overt sign of development. The commencement of ovarian and oviductal growth and the associated steady increase in the concentration of plasma luteinizing hormone (LH) mark the second stage of development (Sharp, 1980). Four to eleven d post-photostimulation a follicular hierarchy begins to form as yellow yolk is deposited into a relatively small number of follicles (Bacon and Cherms, 1968). Ovulation occurs 9 to 10 d after the follicle reaches 8 mm in diameter (Hocking *et al.*, 1987b). The final stage is marked by the first oviposition which occurs between 19 and 31 d after photostimulation (Bacon and Cherms, 1968).

Increased selection emphasis for growth traits in meat-type birds has resulted in diminished reproductive output (Hocking *et al.*, 1987a; Nestor *et al.*, 1980). Male line and female line turkeys are the result of genetic selection primarily for growth and carcass traits or reproductive traits, respectively. Hocking *et al.* (1987a) and Lupicki (1994) found that full fed broiler breeder hens had significantly more large yellow follicles and thus, poorer egg production than full fed Leghorn hens. Feed restriction is a common practice of broiler breeder management where it is used to restrict BW and improve production of settable eggs (Summers and Robinson, 1995). However, feed restriction has not become a standard practice in turkey breeder hen management (Renema *et al*, 1994). Hocking (1992) found that feed restriction was less effective in reducing the number of large yellow follicles and improving egg production in heavy weight lines of turkey hens than it was in light weight lines.

A potential source of reproductive loss of heavy male line hens is that of

"unreconciled" ovulations that occur early in lay. Renema *et al.* (1995) reported that male line hens killed at sexual maturity (first oviposition) had an average of 4.9 unreconciled post-ovulatory follicles (POF). The fate of these ovulated follicles is unclear but, they may represent internal ovulations. It is hypothesized that in male-line hens oviduct development is retarded, or alternatively that ovary development is accelerated. Hence, ovulated follicles are unable to be released into the infundibulum and to be successfully transported through the oviduct, for deposition of albumen, shell membranes and shell. It is unknown if the incidence of unreconciled ovulations is limited to stocks of turkeys that are intensively selected for growth rate, or if this condition is also seen in lines of hens of lower BW that have been selected for reproductive traits as well. Successful capture of these unreconciled ovulations may represent a potential improvement of approximately five eggs per hen.

This paper characterizes and contrasts the development of the reproductive system (ovary and oviduct), body weight and carcass characteristics in male and female lines of turkey hens at sexual maturity. Two groups of birds were used to characterize development on a chronological basis through the transition from a pullet to a hen (Group A) or at sexual maturity (Group B).

Methods and Materials

Stocks and Management

A total of 150 females each of a male line and a female line were reared according to the current management protocols of Hybrid Turkeys Inc. (Kitchener, ON). These two lines represented birds primarily selected for growth traits or reproductive traits, respectively. The

birds were housed in a light controlled laying barn during the experiment. At 29 wk of age birds were photostimulated from 8 h of light to 14 h of light in a 24 h period (8L:16D to 14L:10D). According to Hybrid Turkey Inc. protocol, male line birds and female line birds are routinely photostimulated at 28 wk and 30 wk, respectively. One hundred birds of each line with BW closest to the line mean 28-wk BW were randomly assigned to a study time (Table 1). Four birds from each line were blood sampled and killed every 3 d for a 39 d period (Group A; 14 kill days in total). A second group was used to investigate morphological differences between the lines at sexual maturity (Group B). These birds were blood sampled in the afternoon at 6 d intervals between 28 wk of age and sexual maturity. At 31 wk, all birds were palpated daily each morning 1 h after the lights went on for the presence of a hard shelled egg in the oviduct. Daily palpation ensured accurate determination of day of sexual maturity (first oviposition) in all birds and of individual egg production in Group A birds. Birds were placed in a trap nest if a hard shelled egg was detected. Nests were checked 12 times per day on an hourly basis. Immediately following first oviposition, Group B birds were deprived of feed and water for 12 h and killed.

Reproductive Organ Morphology

In both Group A and Group B birds, the BW, weight of ovary, stroma (ovary without large follicles), oviduct, liver, abdominal fat pad, and breast muscle were recorded for each bird. The number, weights, and diameters of large yellow follicles (diameter greater than 10 mm) were also determined. The number of POF and atretic follicles present on the ovary was also determined. The reconciled age of first ovulation was calculated by subtracting POF

number from the day of first egg after accounting for eggs laid and follicles in the oviduct. Incidence of internal ovulation was recorded as evidenced by the presence of yellow yolky material in the body cavity. Large yellow follicles were sorted into a hierarchy based on size. To determine the potential for multiple ovulations, follicles of similar size (differing by less than 1 g or 1 mm diameter) were assigned to the same position in the hierarchy as described previously by Renema *et al.* (1995).

Carcass Composition

Dissected organs were returned to the carcass which was stored at -15°C until whole carcass analyses was performed as described by Renema *et al.* (1994). Briefly, frozen carcasses were cut into pieces and processed twice through a large meat grinder. A 2 kg ground sample was pressure-cooked for 6 h and homogenized in a large blender. A 100 g subsample was freeze dried for 7 d and subsequently ground in a coffee grinder. Moisture loss during homogenization, storage and freeze drying were corrected for and total carcass content of dry matter, crude protein, lipid and ash were determined using chemical analysis procedures (AOAC, 1980).

Plasma Traits

Individual blood samples were collected via the brachial vein immediately prior to killing. Plasma was stored at -15°C following centrifugation. Plasma lipid concentration was determined using the Folch lipid extraction method (AOAC, 1980).

Plasma estradiol-17β concentration was measured in duplicate by radioimmunoassay

(RIA). The assay used was a solid phase assay (Diagnostic Products Corp., Los Angeles, CA 90045) involving no extraction procedure. Recovery averaged 102.7%, when tested by spiking 1.95, 7.81, 31.25, 62.5, and 250 pg/ml, respectively, of Estradiol-17β with 25 uL of control plasma. Parallelism was determined by measuring the Estradiol-17β concentration in 25, 50, 100, 200, and 400 uL of a plasma pool. The concentrations of Estradiol-17β (pg/ml) was (mean +/- SD) 2.82 +/- .13, 5.77 +/- .22, 11.95 +/- .27, 23.97 +/- .68, and 47.48 +/- 1.22 respectively for the above mentioned volumes. The intra-assay coefficient of variation was 7.03%. All samples were assayed in a single assay. The sensitivity of the assay was 98.4% (15.6 pg/ml). The antiserum was highly specific for Estradiol-17β; its cross-reactivity (reported by the manufacturer) was 4.4% with *d*-Equilenin, 10% with Estrone, 1.8% with Estrone-B-D-glucuronide, 1.8% with Ethinyl Estradiol; and less than 1% with 37 other steroids.

Statistical Analysis

Two male line birds were removed from the data set as their development was significantly delayed as compared to the other birds studied at the same age. Data were analyzed using one-way analyses of variance using SAS (SAS Institute, 1992). Sources of variation were lines (male line and female line) and error variation of birds within lines. Pearson correlation coefficients between reproductive characteristics were computed across all groups. Polynomial regression equations were computed for each trait (ovary and oviduct as percentages of mature organ weight) by line (Group A, Group B) combination using mean values at each age by line by trait combination. The powers of the polynomial regression

equations (5th power for oviduct and 6th power for ovary) were those which gave goodness of fit similar to Lowess smoothing procedure. The polynomial regression equations were used to determine the age of the 100% mature weight of the ovary and the oviduct of both lines.

Results and Discussion

Male line birds had significantly greater BW than the female line birds at all ages (Figure 1). At sexual maturity male line birds had significantly heavier breast muscle mass (4.67 kg *vs.* 3.06 kg respectively) and heavier livers (170.34 g *vs.* 132.05 g) than female line birds (Table 2). The weight of the abdominal fat pad (298.58 g male line: 295.78 g female line) was not significantly different. As the female line had a lower BW and a fat pad equivalent weight to that of the male line, fat pad as a percentage of BW was lower for male line hens than for female line hens (1.88% *vs.* 2.43%, respectively). Total carcass lipid as a percentage of BW was significantly lower in male line hens than in female line hens (22.79% *vs.* 24.76%, respectively), while total carcass water was higher in male line hens than in female line hens (49.42% *vs.* 47.33%, respectively) (Table 3). Breast muscle weight as a percentage of BW was significantly greater for the male line hens than for the female line hens (29.36% *vs.* 25.16%, respectively). However, carcass protein content (as a percentage of BW) was similar between the two lines (22.75% and 22.63% for the male line and female line hens, respectively). Hence, female line hens have similar protein reserves to male line hens, but have a greater carcass fat content than the male line hens. These results demonstrate the effect of selection for growth traits, such as breast muscle development, and FCR selection,

in the male line. Male line hens are leaner than female line hens and have a larger proportion of protein deposited as breast muscle. The weight of the liver, ovary, and oviduct did not significantly differ on a percentage of BW basis between lines.

The mean age at sexual maturity as indicated by the timing of the first oviposition was similar for both lines (233.3 d *vs.* 231.9 d for the male line and female line hens, respectively). Plasma estradiol-17β concentrations peaked at 230 d for both lines (93.0 pg/ml male line; 118.5 pg/ml female line) (Fig. 2). At 227 d and 230 d the male line birds had significantly lower concentrations of plasma estradiol-17β than the female line birds. At the mean age of first oviposition (233 d male line; 232 d female line:) the plasma estradiol-17β concentrations were 68.3 pg/ml for the male line and 86.8 pg/ml for the female line. Plasma lipid concentrations increased gradually for both lines throughout the study and were not significantly different between the lines except at 242 d (Fig. 3).

Birds from both lines first experienced a significant increase in ovary weight between 224 and 227 d of age which corresponds to 18 d and 21 d post photostimulation for male line and female line birds, respectively (Fig. 4). This greater than 200% increase in ovary weight was due to the rapid deposition of yellow yolk to a relatively small number of follicles. The oviduct of the female line had a significant increase in weight between the ages of 224 d and 227 d, while in the male line this occurred between the ages of 227 d and 230 d (Fig. 5). Rapid yolk deposition has previously been reported to occur 4 to 11 d post photostimulation (Bacon and Cherms, 1968). However, in the present experiment, significant increases in ovary weight occurred 18 d post-photostimulation for both lines. The ovary weights of the two lines increased proportionately at the same rate (Fig. 6). This rapid yolk deposition resulted in an

increased number of follicles at sexual maturity in the male line hens as compared to the female line hens (17.41 *vs.* 14.54, respectively). Follicles were more likely to be in a multiple hierarchical arrangement in male line hens, as the number of follicles was positively correlated with the proportion of follicles in a multiple arrangement ($r=.69$, $p<.0001$). Female line birds had a greater proportion of follicles in a single or double hierarchy arrangement than male line birds (Figure 7), while male line birds had a greater proportion of follicles in a triple or a quadruple or larger hierarchical arrangement than female line birds. With multiple hierarchical arrangements, multiple ovulations are likely to occur (Yu *et al.*, 1992). Multiple ovulations can result in some degree of internal ovulation or in poor shell calcification if more than one follicle is occupying the shell gland (Hocking *et al.*, 1992; Yu *et al.*,1992). The incidence of internal ovulation was not significantly different between lines (70.8% female line *vs.* 87.5% male line) in the present experiment.

The number of unreconciled POF immediately at first oviposition was significantly greater in male line hens than in female line hens (3.0 *vs.* 1.6, respectively). Renema *et al.* (1995) reported that male line hens had an average of 4.9 POF at first oviposition. The difference in number of POF between the male and female lines may be explained by asynchronous development of the oviduct and ovary. The number of POF is positively correlated by with the incidence of internal ovulation ($r=.44$; $P<.002$). Figures 8a and 9a show the ovary and oviduct as a percentage of the organ weights at sexual maturity for female line and male line birds, respectively. The relative weight of the developing oviduct as a percentage of mature oviduct weight intersected the 100% line earlier than the developing ovary as a percent of mature ovary weight in both lines. According to the predicted values

of a polynomial regression, the development of the ovary in the female line is delayed by 3 d as compared to the oviduct (Fig. 8b), whereas ovarian and oviductal development occurred simultaneously in male line hens at 232 d (Fig. 9b).

There was no significant difference in mean age at sexual maturity for the female line and the male line (232 d *vs.* 233 d, respectively). This is 26 d and 27 d after photostimulation for the female and male lines respectively. Bacon and Cherms (1968) stated that first oviposition should occur 19 d to 31 d post photostimulation, a range of 12 d. The birds used in this experiment came into production near the latter end of this range. It is possible that with increased emphasis on selection for growth traits, age at sexual maturity has been delayed and/or selection emphasis for reproductive traits has decreased the age at sexual maturity (Nestor, 1971). Male line birds exhibited more variation in the age of sexual maturity (CV 2.70% *vs.* CV 1.94%, respectively) and less variation in the BW at sexual maturity (CV 3.3% *vs.* CV 5.9%, respectively), as compared to the female line birds (Fig. 12). Robinson *et al.* (unpublished data) found that the CV of age and BW at sexual maturity decreased as the age of photostimulation increased. As the age of photostimulation increases, the flock responds more uniformly as more individuals in the population have reached a prerequisite critical body mass to start laying.

The processes of ovulation and oviposition first occur when the oviduct and ovary are developmentally mature. If the ovary matures before the oviduct, ovulations can occur resulting in internal ovulation rather than oviposition. These data indicate that the development of the ovary in male line hens may be accelerated relative to the development of the oviduct. The oviduct of both lines and the ovary of the male line reached their mature

weights at 32 d after photostimulation (238 d of age), while the ovary of the female line reached its mature weight 3 d later (241 d of age). The female line had fewer unreconciled POF and a numerically lower incidence of internal ovulation compared to the male line. These data suggest that maturation of the ovary 3 d after that of the oviduct in the female line results in successful capture of follicles by the oviduct and subsequent oviposition. Managing male line hens in manner so as to accelerate development of the oviduct or slow ovary development may permit breeders to obtain additional settable eggs. Further research is needed to determine the extent to which management strategies such as lighting programs with gradual, long-term increases in day length may play a role in meeting this objective.

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TABLE II-1. Number of turkey hens sacrificed for each study time of Group A and Group B

Group	Age (d)	Days Post-photostimulation	Male Line n =	Female Line n =
A	206	0	4	4
A	209	3	4	4
A	212	6	4	4
A	215	9	4	4
A	218	12	4	4
A	221	15	4	4
A	224	18	4	4
A	227	21	4	4
A	230	24	4	4
A	233	27	4	4
A	236	30	4	4
A	239	33	4	4
A	242	36	4	4
A	245	39	4	4
B	1 day after first oviposition	21 - 43	24	24

TABLE II-2. Age at first egg, body weight and selected organ weights and plasma traits of female line and male line turkey hens killed on the day following first oviposition (Group B)

	Female line	Male line	SEM
No. of hens	24	24	
Age at first egg (d)	232.0	233.3	1.11
Reconciled age at first egg (d)	230.25	230.29	1.25
BW (kg)	12.14^{b}	15.90^{a}	.13
Breast weight (kg)	3.06^{b}	4.67^{a}	.06
Breast weight (%)[1]	25.16^{b}	29.36^{a}	.35
Liver weight (g)	132.05^{b}	170.34^{a}	5.23
Liver weight (%)	1.08	1.07	.03
Fat pad weight (g)	295.78	298.58	15.06
Fat pad weight (%)	2.43^{a}	1.88^{b}	.10
Ovary weight (g)	187.14^{b}	227.63^{a}	8.00
Ovary weight (%)	1.54	1.43	.05
Stroma weight (g)	18.87^{b}	26.10^{a}	1.15
Stroma weight (%)	.16	.16	.04
Oviduct weight (g)	84.80^{b}	109.24^{a}	2.45
Oviduct weight (%)	.70	.69	.02
No. of large yellow follicles	14.54^{b}	17.41^{a}	.65
No. of unreconciled post-ovulatory follicles	1.63^{b}	3.04^{a}	.42
Plasma lipid concentration (%)	1.59	1.55	.79
Plasma estradiol-17β concentration (pg/ml)	86.84^{a}	68.31^{b}	5.50

^{a,b} Means within a row with different superscripts are significantly different ($P<0.05$).
[1] percentage of BW

TABLE II-3. Carcass composition of female line and male line turkey hens killed on the day following first oviposition (Group B)

	Male line	Female line	SEM
H_2O weight (%)[1]	47.33[b]	49.42[a]	.76
H_2O weight (kg)	573.83[b]	785.50[a]	12.08
Crude protein weight (%)	22.63	22.75	.31
Crude protein weight (kg)	2.75[b]	3.61[a]	.04
Lipid weight (%)	24.76[b]	22.79[a]	.71
Lipid weight (kg)	3.02[b]	3.63[a]	.12
Ash weight (%)	3.49	3.50	.07
Ash weight (kg)	.42[b]	.56[a]	.01

[a,b] Means within a row with different superscripts are significantly different ($P<0.05$)

[1] percentage of BW

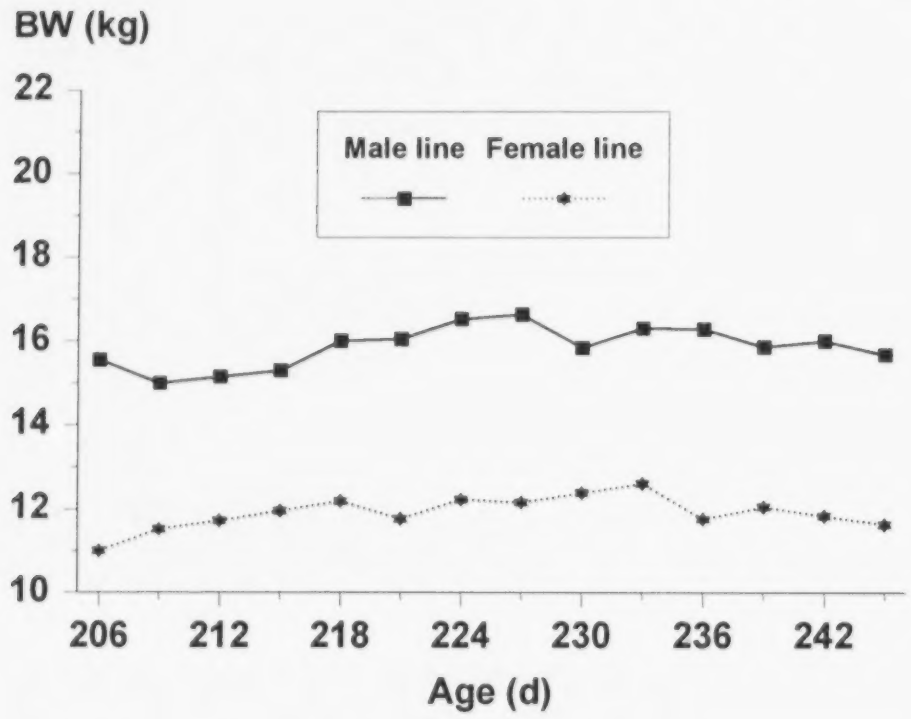

FIGURE II-1. Bodyweight of male line and female line turkey hens from photostimulation to 245 d of age

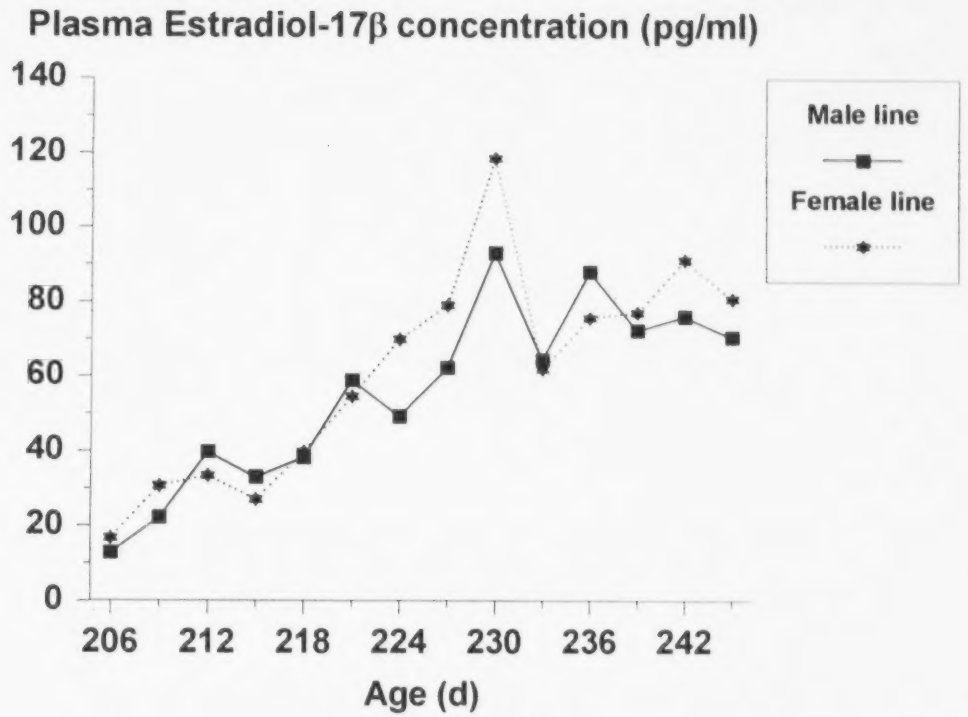

FIGURE II-2. Plasma Estradiol-17β concentrations of male line and female line turkey hens from photostimulation to 245 d of age

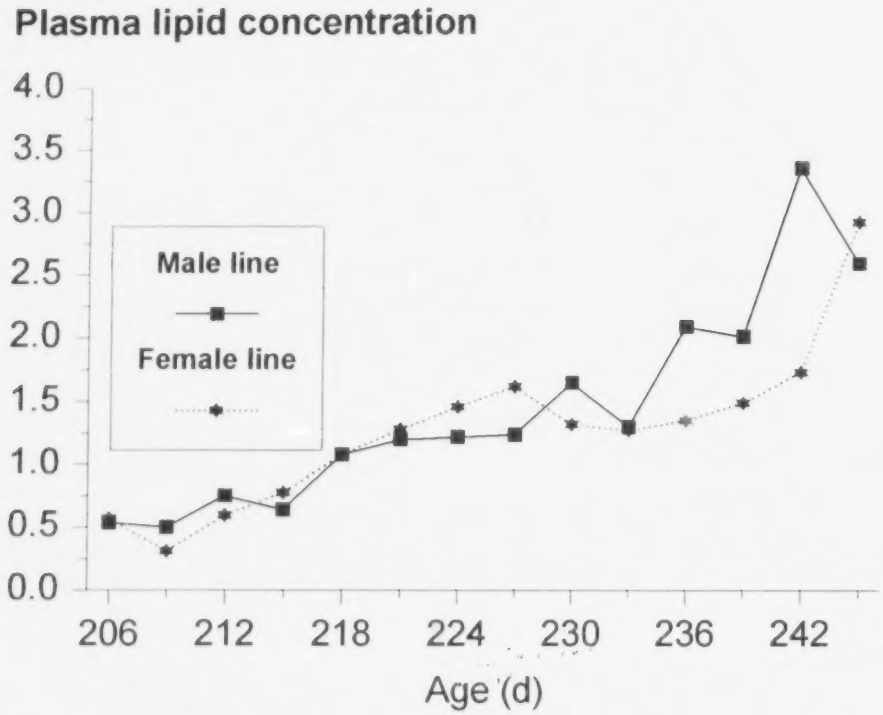

FIGURE II-3. Plasma lipid concentration of male line and female line turkey hens from photostimulation to 245 d of age

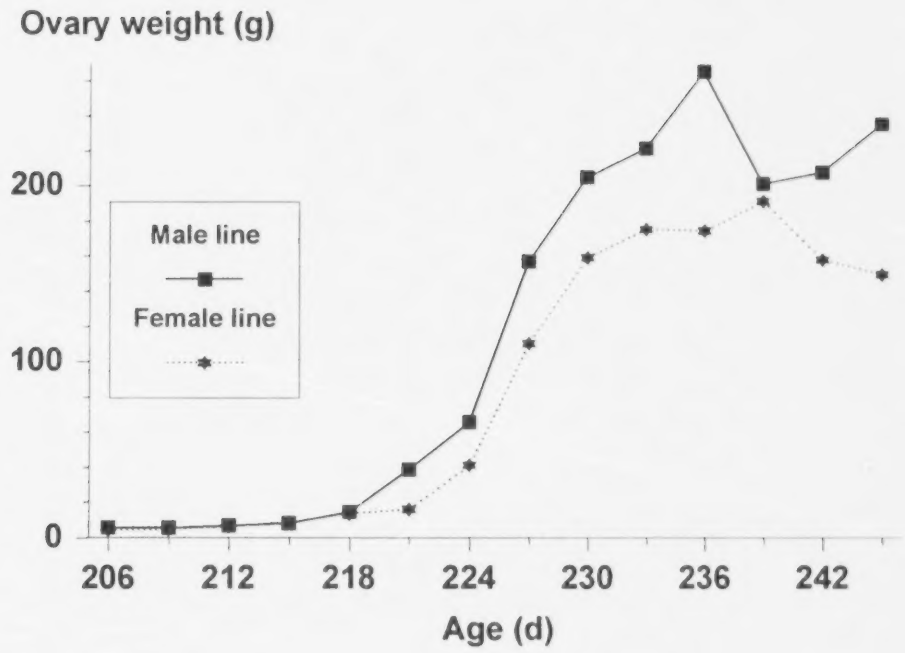

FIGURE II-4. Ovary weight of male line and female line turkey hens from photostimulation to 245 d of age

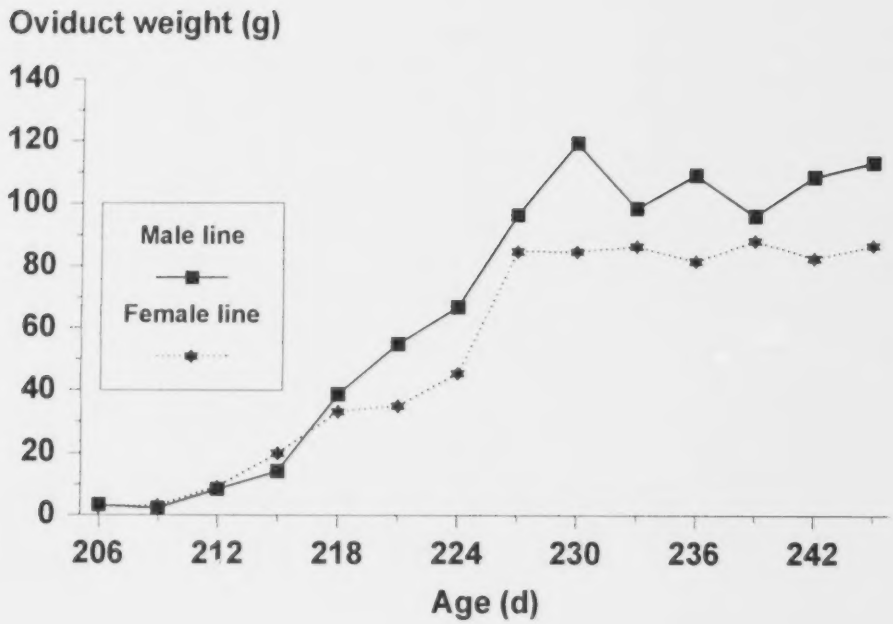

FIGURE II-5. Oviduct weight of male line and female line turkey hens from photostimulation to 245 d of age

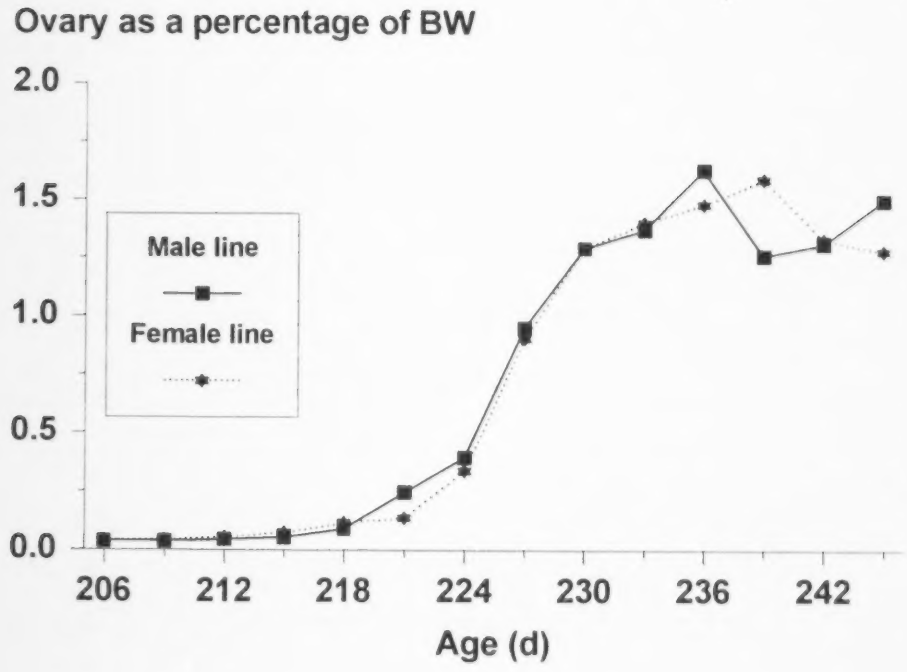

FIGURE II-6. Ovary weight as a percentage of BW of male line and female line turkey hens from photostimulation to 245 d of age

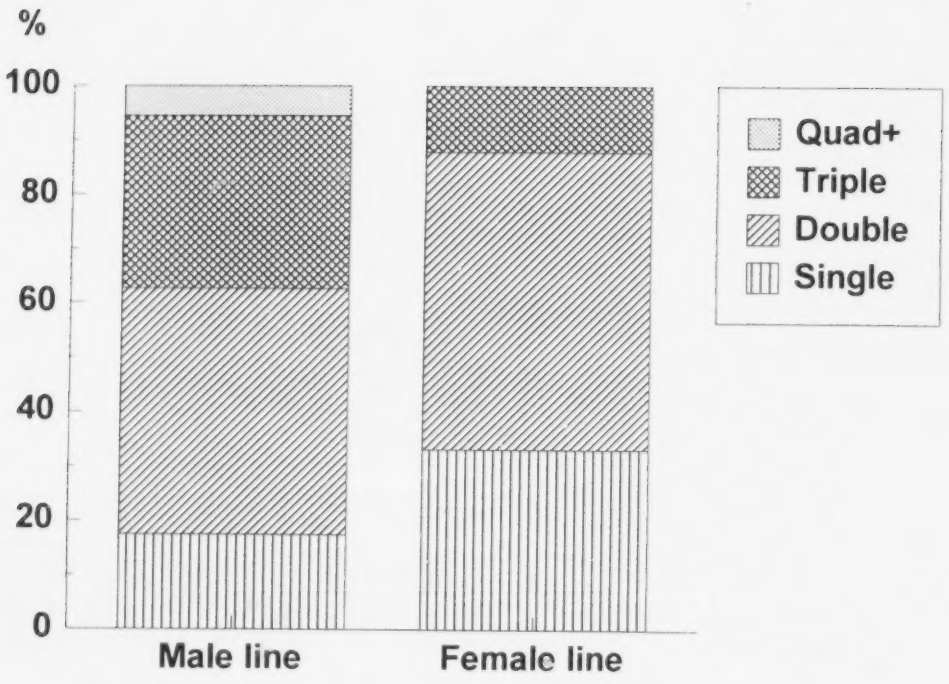

FIGURE II-7. Multiple large yellow follicle arrangement in follicular hierarchy of male line and female line turkey hens

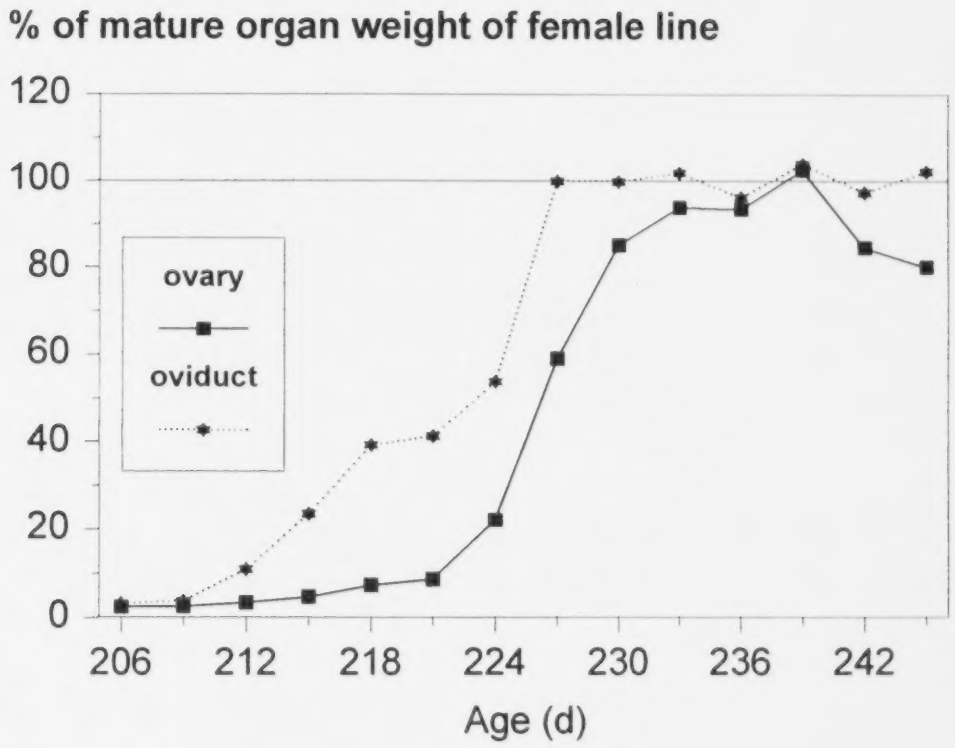

FIGURE II-8 a.Ovary weight and oviduct weight as a percentage of mature organ weight in female line turkey hens

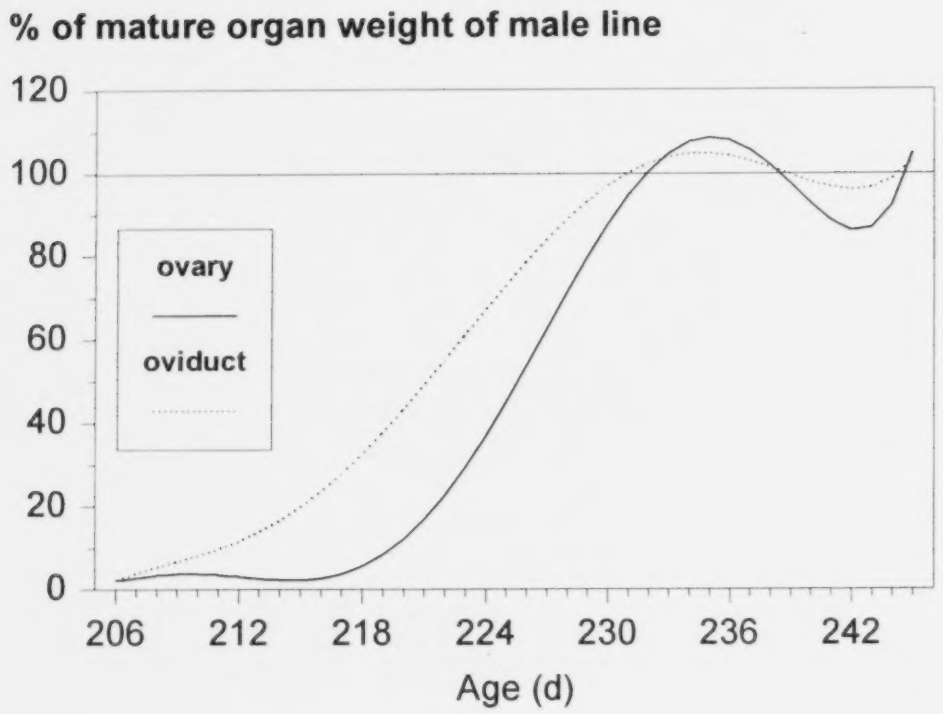

FIGURE II-8 b. Predicted values of ovary weight and oviduct weight as a percentage of mature organ weight in female line turkeys

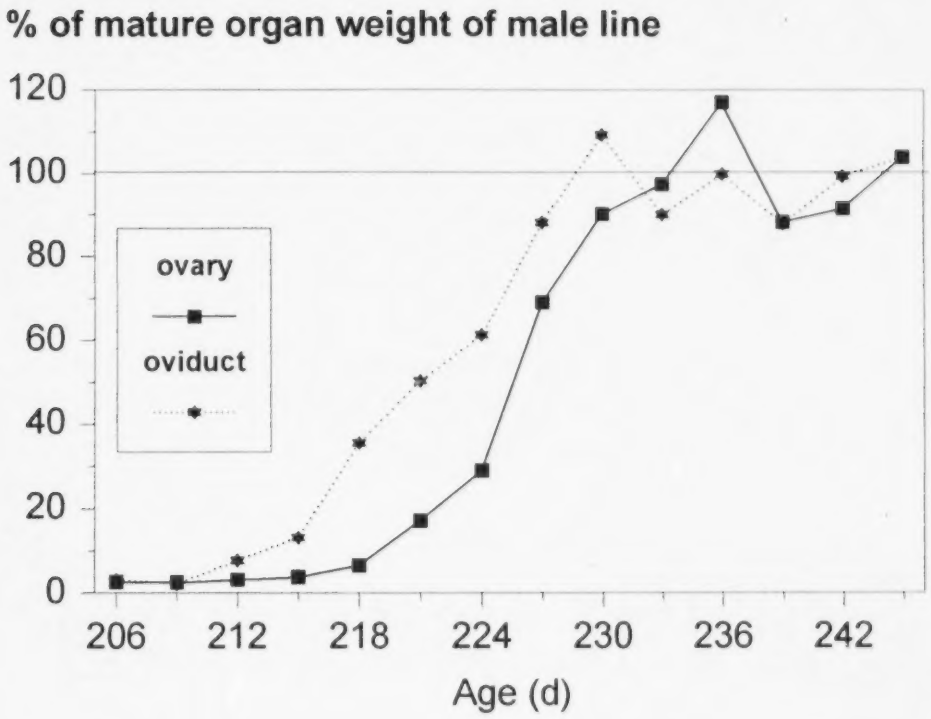

FIGURE II-9 a. Ovary weight and oviduct weight as a percentage of mature organ weight in male line turkey hens

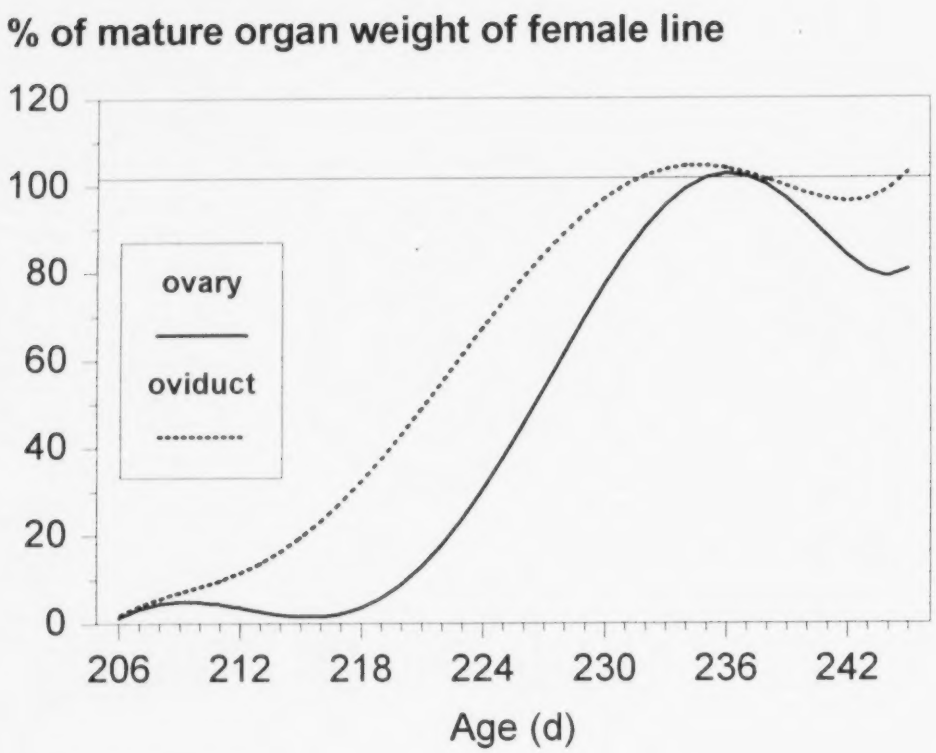

FIGURE II-9 b. Predicted values of ovary weight and oviduct weight as a percentage of mature organ weight in male line turkeys

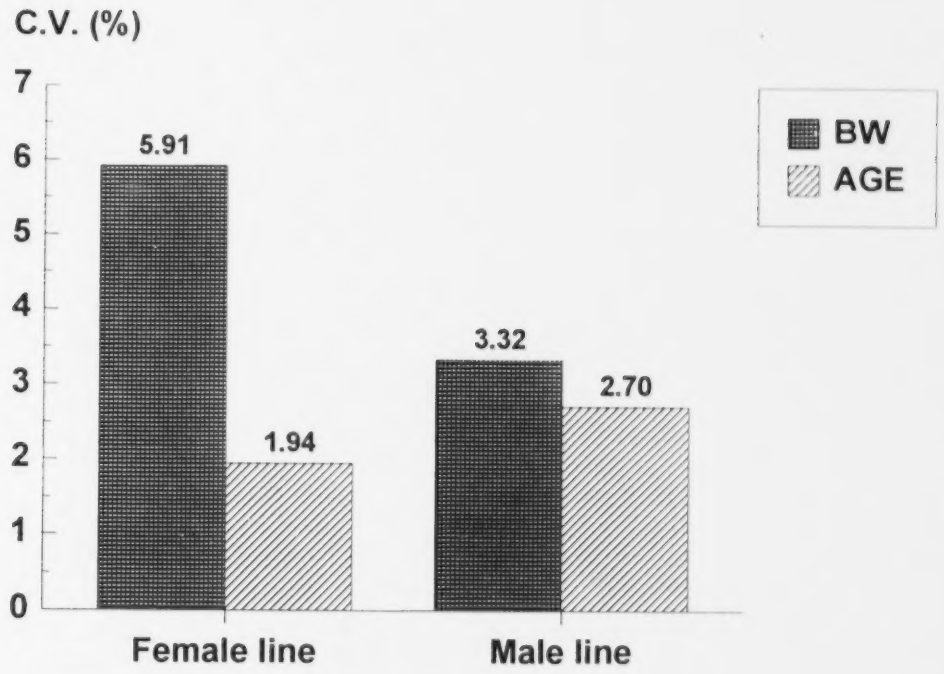

FIGURE II-10. Coefficient of variation of BW and age at sexual maturity of male line and female line turkey hens

III. EFFECTS OF PHOTOSTIMULATION PROGRAM ON REPRODUCTIVE DEVELOPMENT OF FEMALE LARGE WHITE TURKEYS

Introduction

Sexual maturity is the culmination of many physiological events. Factors such as environment and nutrition can alter the developmental responses of an animal and thereby affect production. The timing of photostimulation and the manner in which it is employed will affect the advent of sexual maturity and the subsequent egg production. As the genetics of birds change, as a result of selection pressure, it is possible that physiological responses to environmental stimuli may be altered. It is well understood that photostimulation is necessary to initiate sexual development in turkeys. Turkey poults are hatched in a state of photorefractoriness. In nature, photorefractoriness is dissipated by short photoperiods of winter (< 8 h) (Noll, 1989). Breeding turkeys are housed in controlled photoperiod conditions. In these conditions daylength is shortened for a period of time before photostimulation.

Many studies have investigated the effects of various photostimulation programs on sexual maturity and reproductive function. Providing less than 10 h of light per day has been shown to be adequate to dissipate photorefractoriness (Noll, 1989). The length of the light restriction period also affects the termination of the photorefractory state and subsequent production. There is a general trend of improved egg production following a longer light restriction program (Noll, 1989). Ogasawara *et al.* (1962) showed that 3 wk of light restriction was the minimum needed to dissipate photorefractoriness. Furthermore, Wilson

et al. (1962) found that 6 h of light per day for 3 wk resulted in improved egg production over a light restriction program involving 3 wk of 10 h of light per day. Breeding hens can be photostimulated into production with 11 to 12 h of light per day, although (Marsden *et al.*, 1962; Ogasawara *et al.*, 1962) a photoperiod of 14 to 16 h is necessary to bring hens into maximum egg production (Marsden *et al.*, 1962; Ogasawara *et al.*, 1962). Some studies have investigated the effects of photostimulation programs that would more closely mimic naturally changing daylength. These programs involved gradually increasing in light hours by 30 min/day to 2 h/week (McCartney *et al.*,1961; Marsden *et al.*, 1962, respectively). McCartney *et al.* (1961) did not find any differences in production with abrupt or gradual increases from 9 to 15 h. However, Marsden *et al.* (1962) showed that abrupt changes from 9h to 11, 13, or 15 h decreased the time to first egg and improved egg production for the 11 and 13 h abrupt photoperiods.

Current selection emphasis for primarily growth and carcass traits or reproductive traits have resulted in differences in reproductive potential of different lines of birds. Melnychuk *et al.* (Submitted for publication) have shown that the rate of reproductive organ development is different between male line and female line hens. The ovary of the male line hen matures more quickly than that of the female line hen. The accelerated development of the male line ovary resulted in the loss of approximately three ovulations in the form of internal ovulation due to unsuccessful capture by the oviduct.

This experiment was designed to investigate the effects of a gradual lighting program on the rate of reproductive organ development in commercial breeding stock. The hypothesis of the study was that synchronization of ovary and oviduct development may result in the

improvement of egg production by capturing lost ovulations in early lay.

Methods and Materials

Stocks and Management

A total of 600 day-old female parent stock (Hybrid Turkeys Inc.) poults were randomly assigned to one of four light-tight rooms (150 birds/pen) and received 23 h of light (23L:1D) for 2 d. At 3 d of age two rooms were assigned to a conventional (CON) photostimulation program and two rooms were assigned to an alternate (ALT) photostimulation program. Figure 1 illustrates the CON program, which involved a decrease in light hours at 3 d, 13 wk, 17 wk, 21 wk and 25 wk to 14 h, 8 h, 7 h, 6 h, and 5 h, respectively and an increase in daylength at 29 wk to 14 h of light in a 24 h period (5L:19D to 14L:10D). Figure 2 illustrates the ALT program which involved weekly .5 h decreases in daylength from 3 d to 17 wk (6L:18D), followed by weekly .5 h increases in daylength starting at 20 wk. At 8 wk birds were weighed, wing-banded and relocated to a light controlled barn with four pens per treatment. According to 12 wk BW 200 birds of each treatment with BW closest to the treatment mean were randomly assigned to a study time (Table 1). To characterize reproductive development on a chronological basis, four birds from each treatment were blood sampled and killed at 3 d intervals from 20 wk to 34 wk (Group A) which resulting in a total of 32 kill periods. The second group made up of 24 birds per treatment were used to investigate morphological differences between the treatments at sexual maturity (Group B). These birds were weighed and blood sampled at 6 d intervals between 20 wk and sexual maturity. A final 24 birds per treatment were maintained for egg

production records (Group C). At 30 wk, all birds were palpated daily 1 h after the lights went on for the presence of a hard shelled egg in the oviduct. Daily palpation ensured accurate determination of day of sexual maturity (first oviposition) in all birds and of individual egg production in Group C birds. Birds were placed in a trap nest if a hard shelled egg was detected. Nests were checked 12 times per day on an hourly basis. Immediately following first oviposition, Group B birds were deprived of feed and water for 12 h and killed by injection with T-61. The experimental protocol was approved by the Animal Policy and Welfare Committee of the Faculty of Agriculture, Forestry and Home Economics of the University of Alberta.

Reproductive Organ Morphology

In both Group A and Group B birds, the BW, weight of ovary, stroma (ovary without large follicles), oviduct, liver, abdominal fat pad, and breast muscle were recorded for each bird. The number, weights, and diameters of large yellow follicles (diameter greater than 10 mm) were also determined. The number of POF and atretic follicles present on the ovary were also determined. The reconciled age of first ovulation was calculated by subtracting POF number from the age of first oviposition after accounting for eggs laid and follicles in the oviduct. Incidence of internal ovulation was recorded as evidenced by the presence of yellow yolky material in the body cavity. Large yellow follicles were sorted into a hierarchy based on size. To determine the potential for multiple ovulations, follicles of similar size (differing by less than 1 g or 1 mm diameter) were assigned to the same position in the hierarchy as described previously by Renema *et al.* (1995)

Laying Records

Individual laying records were maintained for Group C birds to 48 wk of age. Daily records included time of oviposition, egg type and egg weight. Eggs were classified into cull categories according to double yolks, small (< 70 g) or shell defects which included membranous eggs and misshapen eggs. Multiple ovulations were calculated according to multiple yolked eggs or multiple egg combinations within a 1 d period. Total eggs produced, total settable eggs, and total cull eggs per bird were determined from individual production records. Data were summarized for four periods throughout the 20 week production cycle (Period 1: wk 0 to 4; Period 2: wk 5 to 9; Period 3: wk 10 to 14; Period 4: wk 15 to19).

Carcass Composition

Livers were removed from the carcass and frozen separately for determination of total liver lipids by petroleum ether extraction (AOAC, 1980). The remaining organs were returned to the carcass which was stored at -15°C until whole carcass analyses was performed as described by Renema *et al.* (1994). Briefly, frozen carcasses were cut into pieces and processed twice through a large meat grinder. A 2 kg ground sample was pressure-cooked for 6 h and homogenized in a large blender. A 100 g subsample was freeze dried for 7 d and subsequently ground in a coffee grinder. Moisture loss during homogenization, storage, and freeze drying were corrected for and total carcass content of dry matter, crude protein, lipid, and ash were determined using chemical analysis procedures (AOAC, 1980).

Plasma Traits

Individual blood samples were collected via the brachial vein immediately prior to killing. Plasma was stored at -15^{0}C following centrifugation. Plasma lipid concentration was determined using the Folch lipid extraction method (AOAC, 1980).

Statistical Analysis

One CON bird and three ALT birds were removed from the data set as their development was significantly delayed as compared to the other birds studied at the same age. Since the study was concerned with characterizing the growth and development of the reproductive organs, one CON bird and two ALT birds were removed from the data set because their ovaries were regressed following a period of lay. One additional bird was removed from the data set due to pendulous crop problems and another died of a sudden death syndrome. Data were analyzed using one-way analyses of variance using SAS (SAS Institute, 1992). Sources of variation were treatments (CON and ALT) and error variation of birds within treatments. Polynomial regression equations were computed for each trait (ovary and oviduct as percentages of mature organ weight) by treatment combination (Group A, Group B) combination using mean values at each age by line by trait combination. The initial age of the polynomial regression equations for each treatment were determined to be at the age of photostimulation for the CON treatment and at the age of initial increases in organ weight for the ALT treatment. The powers of the polynomial regression equations (3rd power for oviduct and ovary) were those which gave goodness of fit similar to the Lowess smoothing procedure. The polynomial regression equations were used to determine the age

of the 100% mature weight of the ovary and the oviduct of both lines.

Results and Discussion

Age and Photoperiod at Sexual Maturity

CON birds were significantly older (224 d *vs.* 220 d) and heavier (11.88 kg *vs.* 11.18 kg) than the ALT birds at sexual maturity (Table 2). The first oviposition in the CON treatment occurred between 217 d and 233 d, while first oviposition in the ALT treatment occurred between 206 d and 233 d (Figure 3). The photoperiod at the mean age at first egg was 14L:10D for the CON treatment and 12L:12D for the ALT treatment. ALT birds exhibited more variation in the age and BW at sexual maturity (C.V. 3.1% age; 6.2% BW) than CON birds (C.V. 3.0% age; 5.7% BW). Reconciled age at first oviposition was calculated by subtracting the number of POF from the age at first oviposition. The treatments did not differ at the reconciled age at first ovipositon.

Carcass Traits

Bodyweight was not significantly different between treatments at all ages examined except at 179 d and185 d (Figure 4). At sexual maturity CON birds had a greater breast weight (Table 2). Abdominal fat pad weight (306.6 g CON *vs.* 311.9 g ALT) and liver weight (166.8 g CON *vs.* 151.1 g ALT) were not significantly different between treatments at sexual maturity. Likewise, liver lipid concentration on a dry matter basis (19.0 CON *vs.* 22.8ALT) was not significantly different as concentrations within both treatments were highly variable (C. V. 56% CON *vs.* 48% ALT). Between 203 d and 215 d liver weight was significantly

greater for ALT birds than CON birds (Figure 5). Although liver lipid concentration was not significantly different between treatments at sexual maturity, plasma lipid concentration was different at 218 d and 236 d (Figure 6). CON plasma lipid concentration increased significantly between 200 and 206 d and between 212, 218, 224 and 230 d, while a significant increase in plasma lipid concentration of ALT birds initially occurred between 206 and 212 d and the between 212, 218, 224 and 230 d. An increase in plasma lipid concentration of CON birds coincides with photostimulation at 203 d. A significant increase in plasma lipid concentration of ALT birds occurred when the daylength was between 11L:13D and 11.5L:12.5D.

Carcass composition was not significantly different between treatments at the 5% significance level (Table 3). However, at the 10% significance level CON birds had significantly less carcass lipid as a percentage of BW than ALT birds (20.87% CON *vs.* 23.58% ALT).

Reproductive Tract Development

At sexual maturity CON birds had significantly greater ovary weight than ALT birds (185.6 g CON *vs.* 143.4 g ALT) (Table 4). Optimally, this decrease in ovary weight of the ALT birds should be due to a reduction in follicle number rather than follicle size. A reduction in follicle size results in smaller egg weights. The number of large yellow follicles was not significantly different between treatments at the 5% significance level but was significant at the 10% level (14.3 CON *vs.* 12.9 ALT) (Table 4). Increased follicle numbers are likely to result in formation of multiple hierarchies of large follicles (Nestor *et al.*, 1980; Hocking

1992; Hocking *et al.*, 1987, 1989). Follicles that differed in weight and diameter by less than 1 g and 1 mm, respectively were sorted into the same position of the hierarchy. CON birds experienced a numerically higher incidence of follicles in a single (38.8% CON; 35.2% ALT) and triple hierarchical arrangement (7.75% CON *vs.* 3.04% ALT) and a numerically lower incidence of follicles in a double hierarchical arrangement (50.6 CON *vs.* 60.7 ALT) (Table 4). These differences were not significant between treatments. Yu *et al.* (1992) found that multiple ovulations are likely to occur as a result of multiple hierarchical arrangements. Internal ovulation or poor shell calcification of more than one egg in the shell gland are often the consequences of multiple ovulations. The incidences of internal ovulation (60% CON *vs.* 61 % ALT) or atresia (40% CON *vs.* 65% ALT) were not significantly different between treatments.

CON birds had significantly lighter ovaries between 206 and 218 d of age, except at 209 d (Figure 7). Ovary development of CON birds is delayed relative to that of ALT birds. The ovary of ALT birds experienced significant weight increases between 203 and 218 d of age, except for decreases at 209 d and 215 d. The photoperiod during this time of rapid growth was 11L:13D to 12L:12D for ALT treatment birds. Ovarian development of ALT birds was subject to a high degree of variability. This variability was due to the fact that four different birds were killed at 3 d intervals. It is likely that individual birds would not experience such variability in ovary development. It is possible that some ALT birds may not have obtained the necessary BW, body composition and energy balance thresholds for sexual development to commence, while some pen-mates had reached these thresholds and responded to the increasing daylength. Ovary development of CON birds was more uniform

than that of ALT birds. Ovary weight of CON birds increased significantly between 215, 218 and 221 d of age. The initial increase in ovary weight of CON birds occurred 12 d post-photostimulation. Bacon and Cherms (1968) reported that rapid yolk deposition occurred 4 to 11 d post-photostimulation. Thus, ALT birds may have received a photostimulatory light signal between 192 and 199 d, which is 4 to 11 days prior to the initial significant increase in ovary weight. The photoperiod at 192 and 199 d was 10L:14D and 11L:13D. Marsden *et al.* (1962) showed that 11 to 12 h of light was adequate stimulation for egg production to commence but that longer daylengths (14 to 16 h) resulted in better egg production.

As with ovarian development, CON birds had significantly lighter oviducts than ALT birds between 197 to 218 d of age (Figure 8). The initial significant increase in oviduct weight occurred between 209 and 212 d of age for CON birds and between 203 and 206 d of age for ALT birds. Oviduct development of ALT birds appears more erratic than that of CON birds. Once photostimulated at 203 d of age, CON experiences a steady increase in oviduct weight to 221 d while ALT birds experience significant decreases in oviduct weight throughout the developmental period.

Figures 9a and 10a show the ovary and oviduct as a percentage of the organ weights at sexual maturity for CON and ALT treatments, respectively. The developing oviduct as a percentage of mature oviduct weight intersected the 100% line at approximately the same age as the ovary did for each treatment. According to predicted values for CON birds, the developing oviduct as a percentage of mature oviduct weight intersected the 100% line 5 d before the developing ovary as a percentage of mature ovary weight did (222 d oviduct, 227 d ovary) (Figure 9b). Conversely, the developing oviduct of ALT intersected the 100% line

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4 days after the developing ovary did (221 d oviduct; 217 d ovary) (Figure 10b). Thus, the ALT lighting program accelerated ovarian growth by 10 d as compared to CON. ALT is highly variable so it is difficult to determine with certainty how the treatments compare. From photostimulation (203 d) to the end of the trial (236 d) 8 of 46 (17%) CON birds did not follow the trend in which the oviduct matures before the ovary. During the same 33 d period 22 of 41 (54%) ALT birds did not follow the trend in which the ovary matures before the oviduct. .

Egg Production

Total egg production and total settable egg production were not significantly different between treatments (Table 5). During the first four wk of production the slope of the egg production curve rises more steeply for the CON treatment than for the ALT treatment (Figure 13). Since the age at sexual maturity was highly variable for the ALT treatment, this was expected, as the rise to peak production would be more spread out, reducing the slope of the curve. The profile of cull eggs was different between treatments. CON birds had significantly fewer small eggs ($P<.05$) and a greater incidence of double yolk eggs ($P<.10$). Studies have shown that birds that are exposed to a light restriction period and then photostimulated before being fully grown, were slow to reach sexual maturity and had small first eggs (Leighton andShoffner, 1961; Sexton and McCartney, 1973). The majority of small eggs occurred in the first four wk of production for both treatments (Table 6). After the first period of egg production the incidence of cull eggs did not differ between treatments. Woodard *et al.* (1974) reported that birds photostimulated from 8L:16D to 16L;8D at 24 and

26 wk had lower egg production over 20 wk than birds photostimulated at 30 wk. Birds that reached sexual maturity early had significantly lighter first eggs than later maturing birds (Woodard *et al.* 1974). CON birds had significantly heavier first egg weights than ALT birds (77.2 g *vs.* 70.6 g, respectively)(Table 5)

Conclusion

Gradual increases in daylength accelerated ovarian development of commercial hens. The ovary of the ALT treatment reached its sexually mature weight 4 d before the oviduct and 10 d before the ovary of the CON treatment. Although the gradual lighting program did not result in sychronized ovarian and oviductal development, the number of unreconciled post-ovulatory follicles did not differ between treatments. The age of sexual maturity differed by 4 d between treatments, however there were no differences in total egg production or settable egg production. The ALT treatment had significantly smaller first eggs and more smaller eggs compared to the CON treatment. Studies have shown that early photostimulation results in smaller first eggs and poorer egg production (Leighton and Shoffner, 1961; Sexton and McCartney, 1973). Adjustments to the timing of initiation of light increases may improve the gradual light program by delaying the age of sexual maturity until all the birds have obtained the prerequisite BW for sexual maturity. A variation of the gradual lighting program may be of value to heavier BW lines of turkeys. Melnychuk *et al.* (submitted for publication) showed that development of the ovary of male line birds is accelerated relative to the oviduct. This asynchronous development resulted in the loss of three potential eggs to internal ovulation early in lay.

ACKNOWLEDGEMENTS

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TABLE III-1. Description of study groups.

Group	Number of kill periods	n (per kill period)	Age range (d)
A-reproductive development	22	4	140-206
B-sexual maturity	1	24	206-233
C-egg production	1	48	n/a

TABLE III-2. Age at first egg, body weight and selected organ weights and plasma traits of CON and ALT hens killed on the day following first oviposition (Group B)

	CON ± SEM	ALT ± SEM
No. of hens	24	23
Age at first egg (d)	224.0[a] ± 1.3	220.2[b] ± 1.4
Reconciled age at first egg (d)	222.4 ± 1.4	219.0 ± 1.5
BW (kg)	11.88 ± .14	11.17 ± .14
Breast weight (kg)	2.93[a] ± .06	2.64[b] ± .06
Breast weight (%)[1]	24.64 ± .36	23.63 ± .37
Liver weight (g)	166.76 ± 6.89	151.13 ± 7.19
Liver weight (%)	1.41 ± .05	1.34 ± .06
Fat pad weight (g)	306.61 ± 15.28	311.85 ± 15.93
Fat pad weight (%)	2.58 ± .12	2.77 ± .13

[a,b] Means within a row with different superscripts are significantly different ($P<0.05$).
[1] percentage of BW.

TABLE III-3. Carcass composition of ALT and CON turkey hens killed on the day following first oviposition (Group B)

	CON ± SEM	ALT ± SEM
H_2O weight (%)[1]	53.73 ± 2.13	49.69 ± 2.22
H_2O weight (kg)	6.36 ± .28	5.71 ± .29
Crude protein weight (%)	22.11 ± 1.03	23.38 ± 1.07
Crude protein weight (kg)	2.60 ± .12	2.70 ± .13
Lipid weight (%)	20.87^{b} ± 1.09	23.58^{a} ± 1.14
Lipid weight (kg)	2.44 ± .14	2.73 ± .14
Ash weight (%)	3.32 ± .17	3.63 ± .17
Ash weight (kg)	.39 ± .02	.42 ± .02

[a,b] Means within a row with different superscripts are significantly different ($P<0.1$).

[1] percentage of BW.

TABLE III-4. Effect of photostimulation program on ovarian morphology at first egg (Group B)

	CON ± SEM	ALT ± SEM
Number of hens	24	23
Ovary weight (g)	185.6^{a} ± 5.39	143.4^{b} ± 5.62
Stroma weight (g)	20.4 ± .98	18.5 ± 1.03
Number of unreconciled post-ovulatory follicles	1.6 ± .28	1.2 ± .29
Number of large yellow follicles	14.3 ± .57	12.9 ± .59
Number of positions in hierarchy	9.4 ± .40	8.5 ± .42
Proportion of follicles in single hierarchy (%)	38.8 ± 4.47	35.2 ± 4.65
Proportion of follicles in double hierarchy (%)	50.6 ± 4.17	60.7 ± 4.35
Proportion of follicles in triple hierarchy (%)	7.8 ± 2.39	3.0 ± 2.49
Incidence of internal ovulation (%)	60.0 ± 10	61.0 ± 10
Incidence of atresia (%)	40.0 ± 10	65.0 ± 10

^{a,b} Means within a row with different superscripts are significantly different ($P<0.05$).

TABLE III-5. Effect of photostimulation program on egg production to 48 wk of age (Group C).

	CON ± SEM	ALT ± SEM
First egg weight (g)	77.2[a] ± 1.57	70.6[b] ± 1.69
Total egg production per hen	70.7 ± 1.83	71.4 ± 1.86
Total settable egg production per hen	68.9 ± 1.90	68.6 ± 1.93
Total small eggs	.5[b] ± .49	2.2[a] ± .50
Total double yolk eggs	.6[a] ± .14	.2[b] ± .14
Total shell defect eggs	.6 ± .14	.4 ± .15

[a,b] Means within a row with different superscripts are significantly different ($P<0.05$).

TABLE III-6. Effect of photostimulation program on cull eggs for four periods during 19 wks of production (Group C)

Egg type	CON	ALT
	--------- (% incidence + SEM)---------	
Small (<70 g)	$.82^{b} \pm .75$	$3.31^{a} \pm .76$
period 1*	$.31^{b} \pm .47$	$1.78^{a} \pm .47$
period 2**	$.44 \pm .52$	$1.53 \pm .53$
period 3***	$.04 \pm .03$	$0 \pm .03$
period 4****	$.04 \pm .03$	$0 \pm .03$
Double-yolk	$.81^{y} \pm .20$	$.31^{z} \pm .20$
period 1	$.35^{y} \pm .12$	$.04^{z} \pm .12$
period 2	$.25 \pm .13$	$.17 \pm .14$
period 3	$.21 \pm .07$	$.05 \pm .07$
period 4	$0 \pm .03$	$.04 \pm .03$
Shell Defects	$.91 \pm .22$	$.52 \pm .22$
period 1	$.04 \pm .04$	$.04 \pm .04$
period 2	$.43^{y} \pm .11$	$.14^{z} \pm .11$
period 3	$.40 \pm .16$	$.29 \pm .16$
period 4	$.04 \pm .04$	$.04 \pm .04$

[a,b] Means within a row with different superscripts are significantly different ($P<0.05$).

[y,z] Means within a row with different superscripts are significantly different ($P<0.1$).

*period 1 = wk 0-4

**period 2 = wk 5-9

***period 3 = wk 10-14

****period 4 = wk 15-19

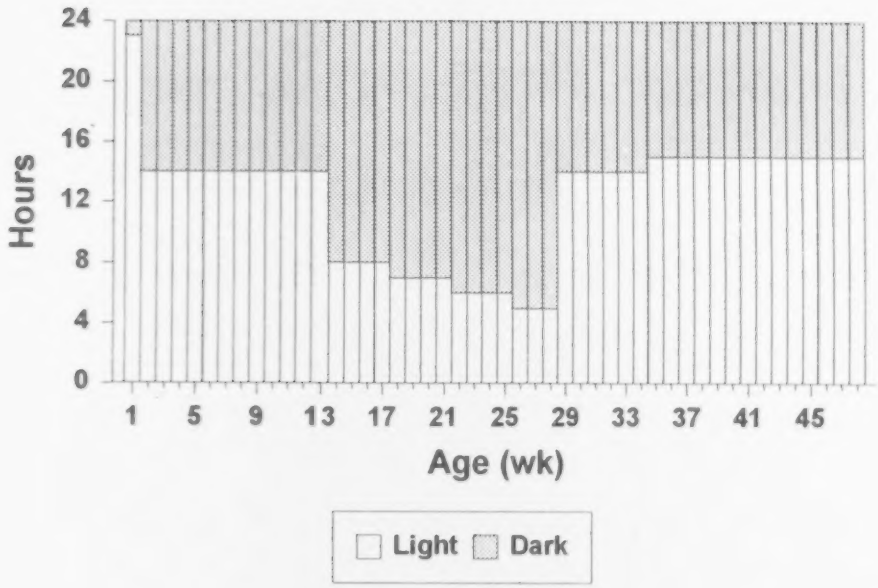

FIGURE III-1. Conventional (CON) photostimulation program

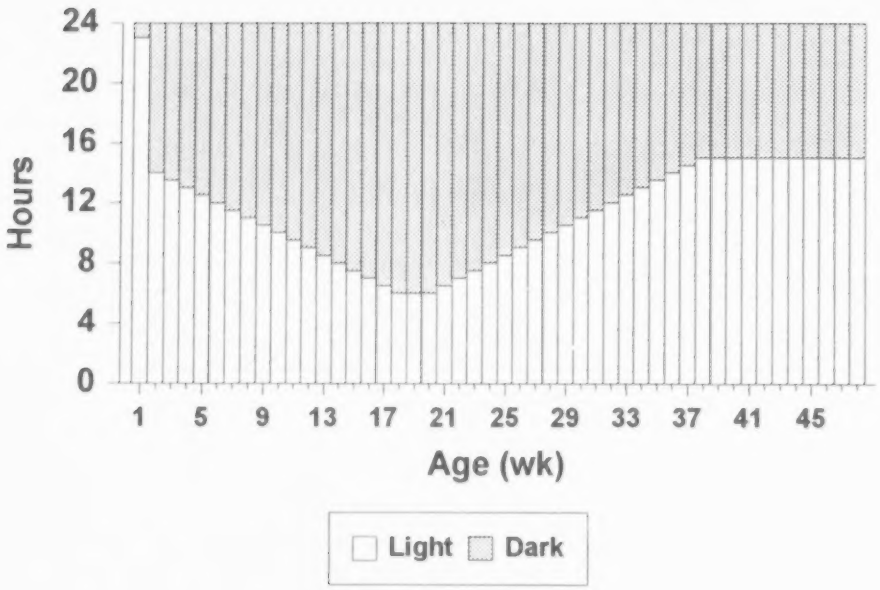

FIGURE III-2. Alternate (ALT) photostimulation program

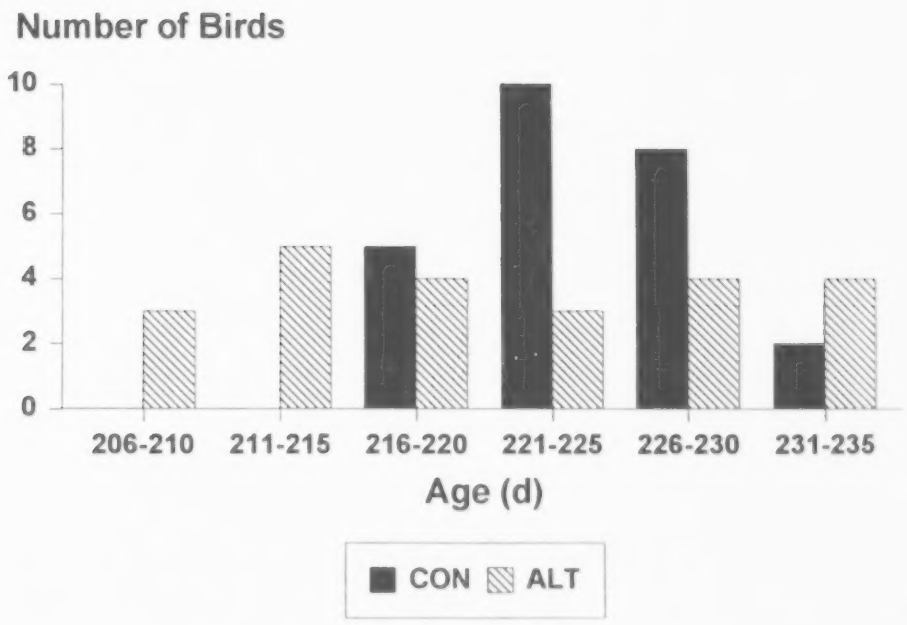

FIGURE III-3. Distribution of age at sexual maturity for CON and ALT turkey hens

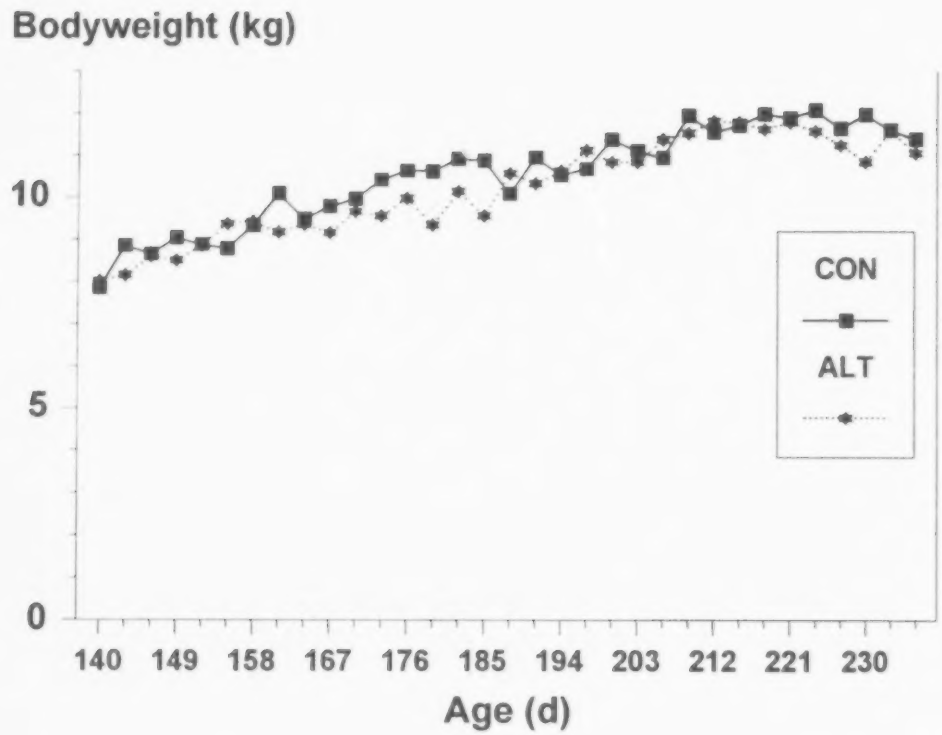

FIGURE III-4. Bodyweight of CON and ALT turkey hens from 140 d of age to 236 d of age

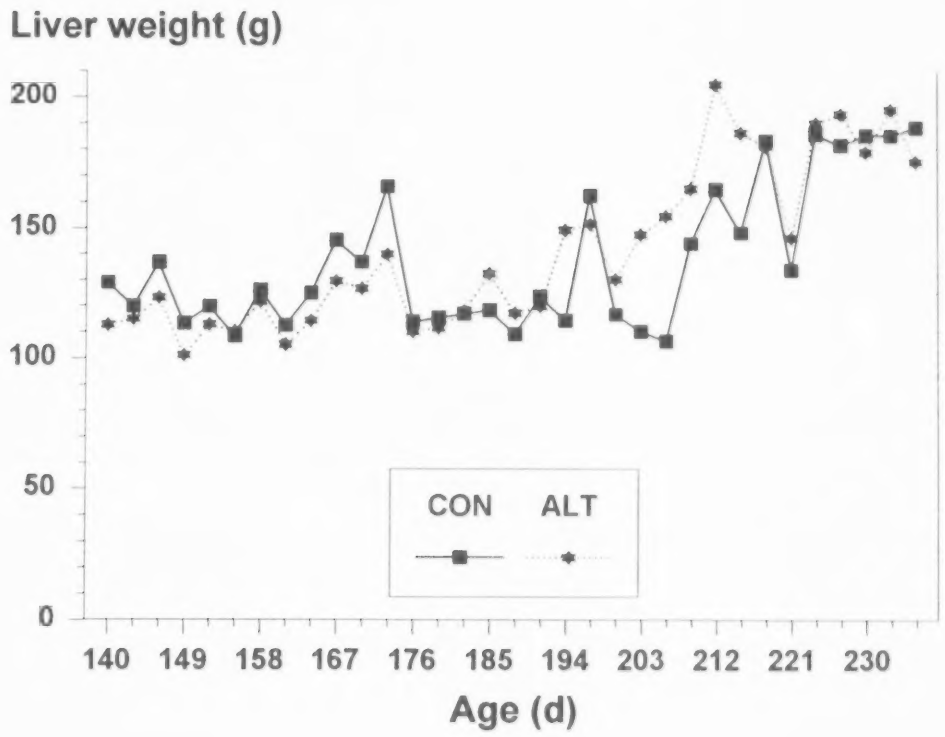

FIGURE III-5. Liver weight of CON and ALT turkey hens from 140 d of age to 236 d of age

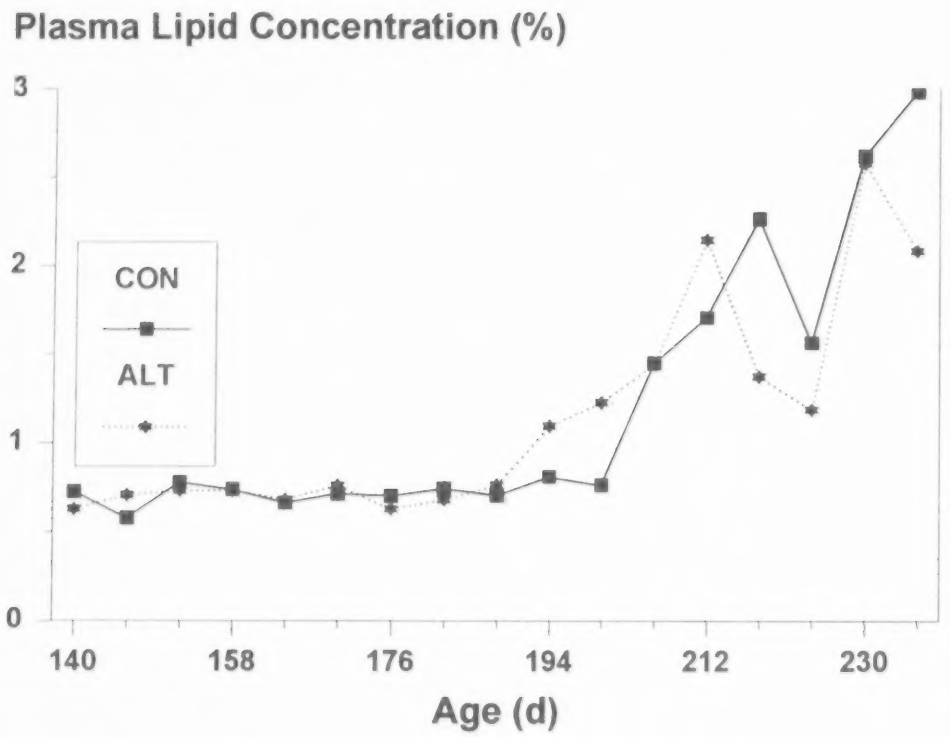

FIGURE III-6. Plasma lipid concentration of CON and ALT turkey hens from 140 d of age to 236 d of age

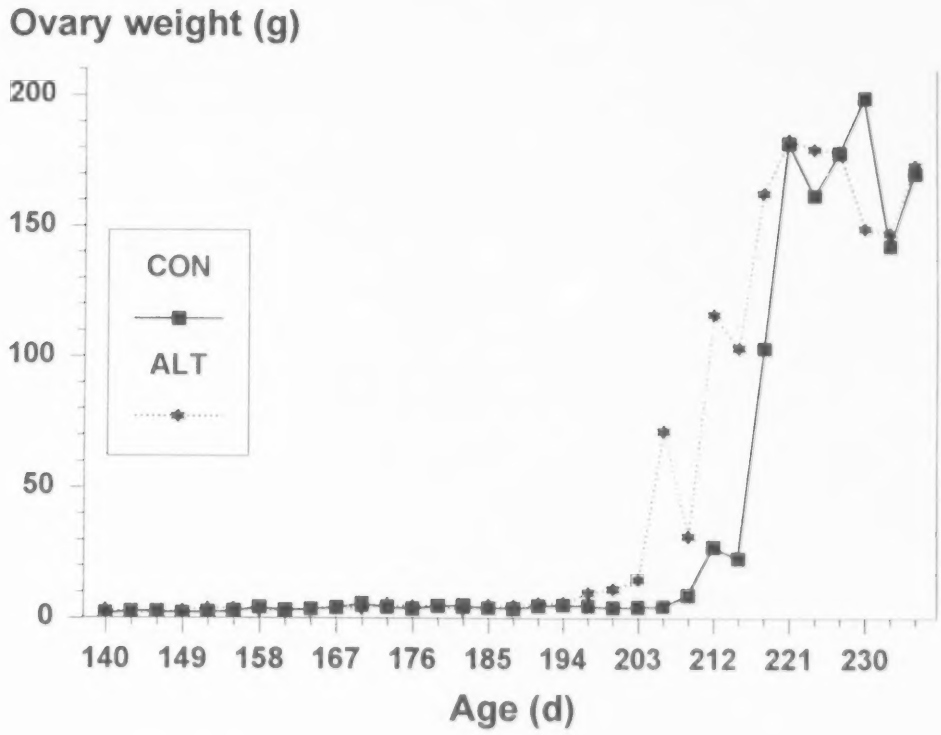

FIGURE III-7. Ovary weight of CON and ALT turkey hens from 140 d of age to 236 d of age

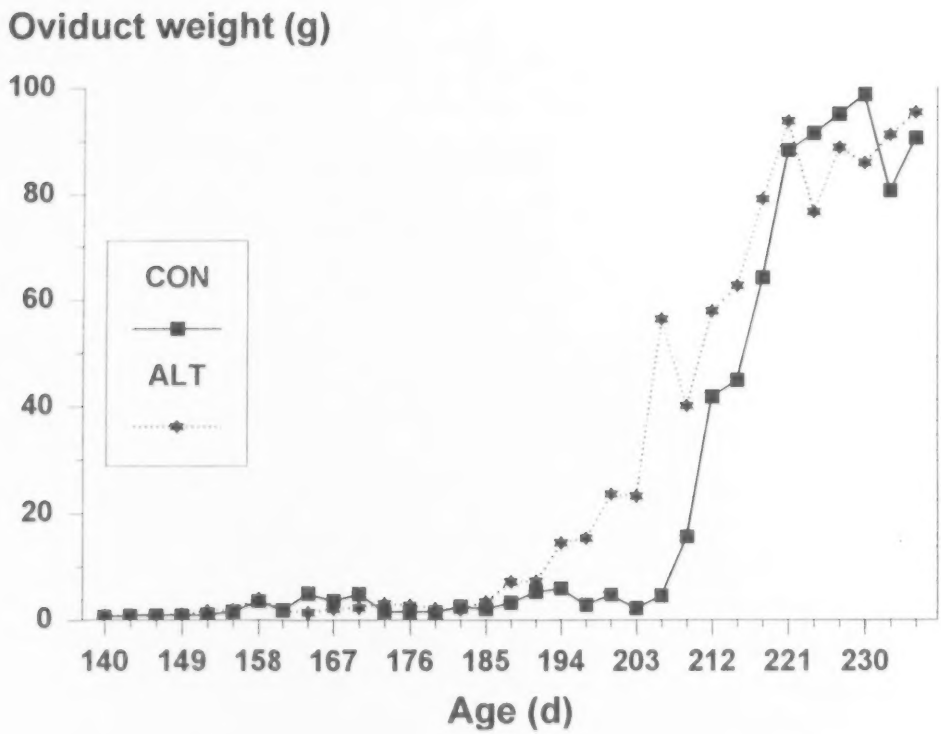

FIGURE III-8. Oviduct weight of CON and ALT turkey hens from 140 d of age to 236 d of age

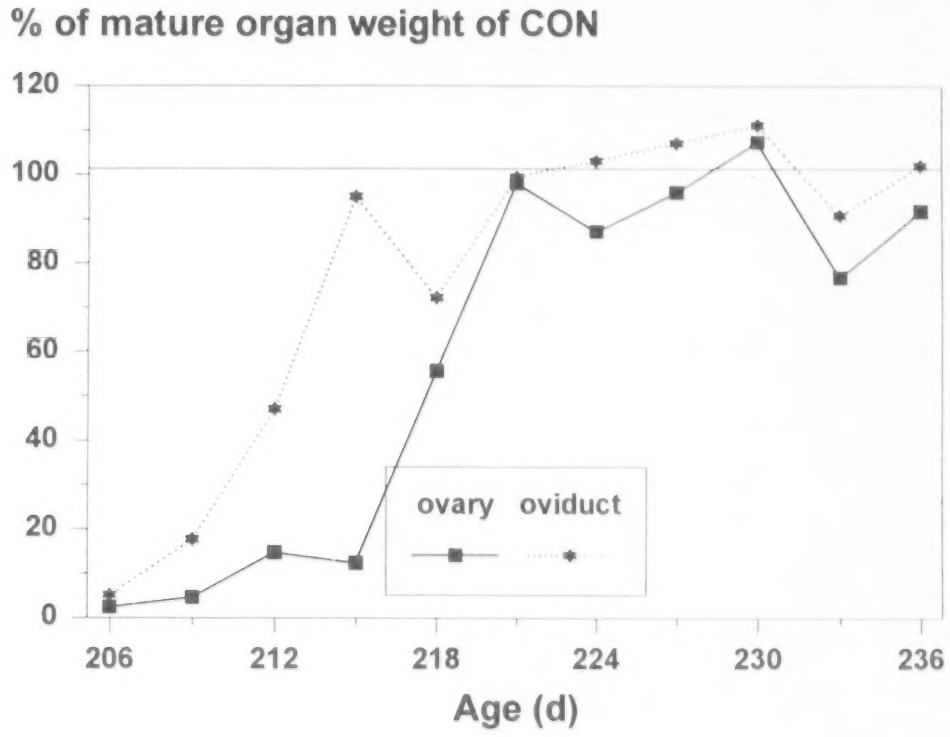

FIGURE III-9 a. Ovary weight and oviduct weight as a percentage of mature organ weight in CON turkey hens

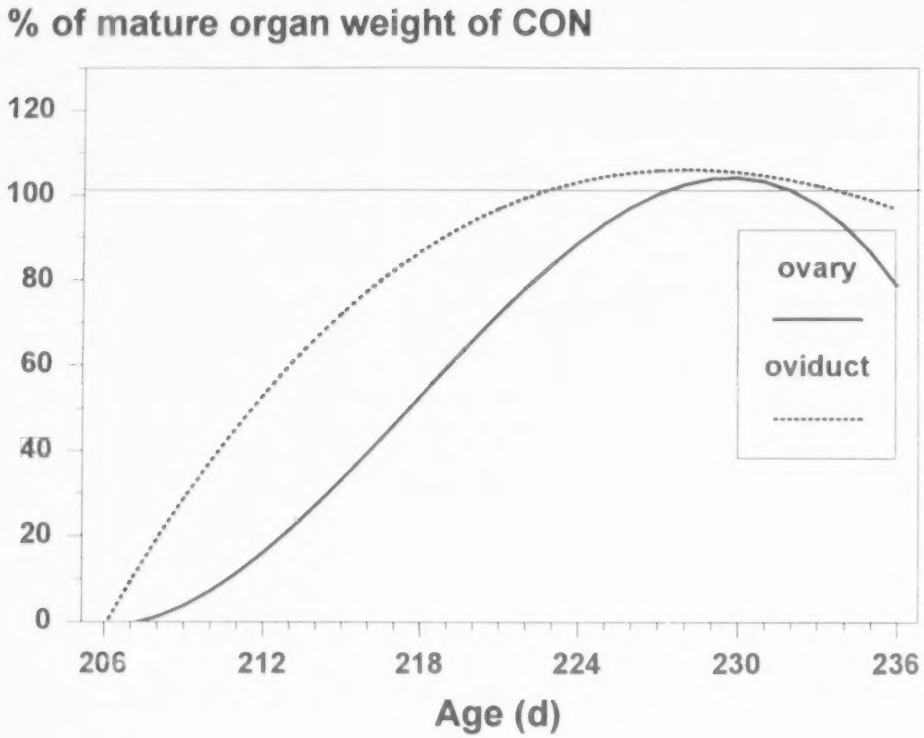

FIGURE III-9 b. Predicted values of ovary weight and oviduct weight as a percentage of mature organ weight in CON turkeys

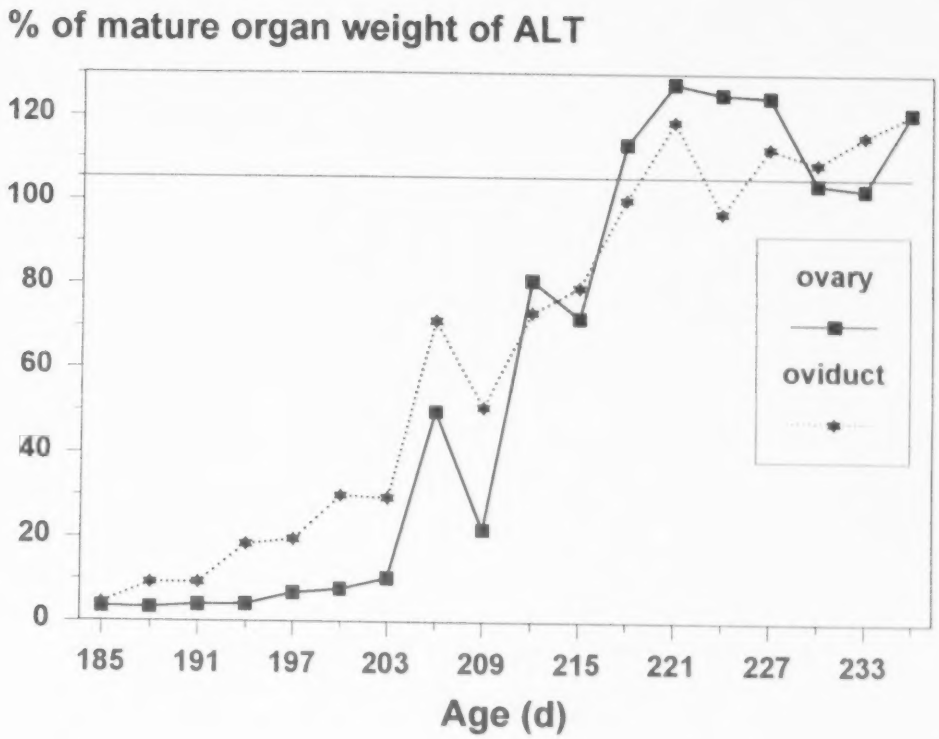

FIGURE III-10 a. Ovary weight and oviduct weight as a percentage of mature organ weight in ALT turkey hens

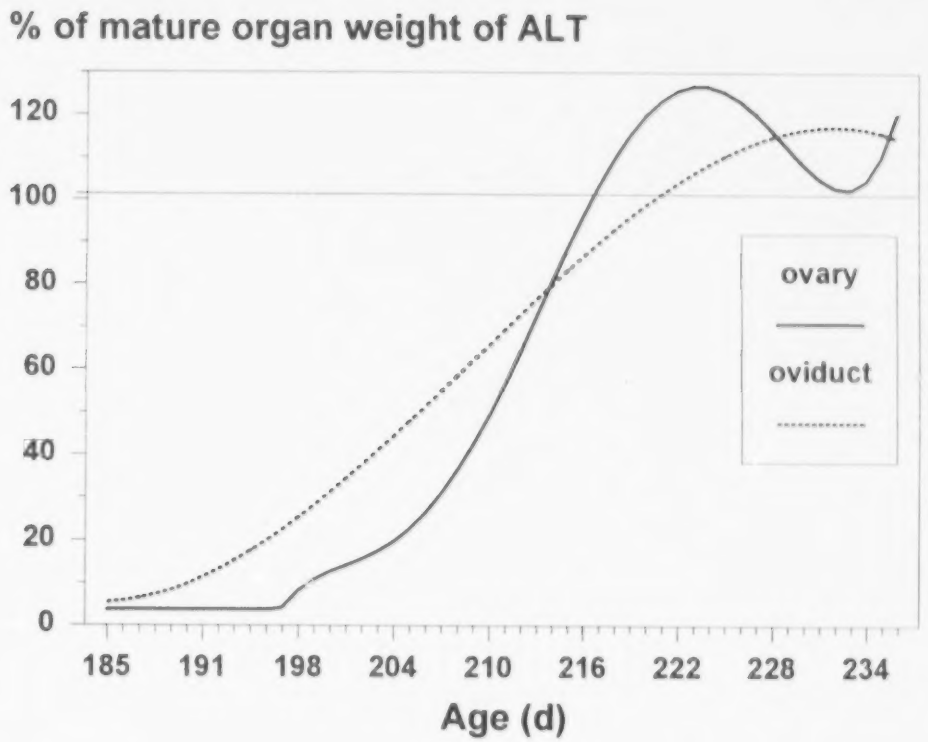

FIGURE III-10 b. Predicted values of ovary weight and oviduct weight as a percentage of mature organ weight in ALT turkeys

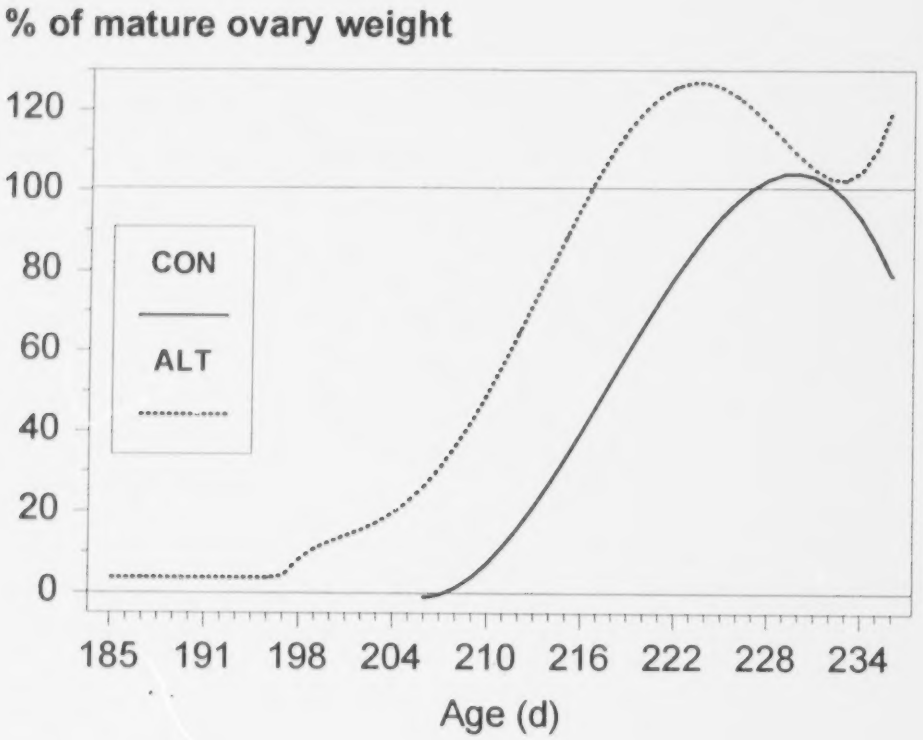

FIGURE III-11. Predicted values of ovary weight as a percentage of mature organ weight in CON and ALT turkeys

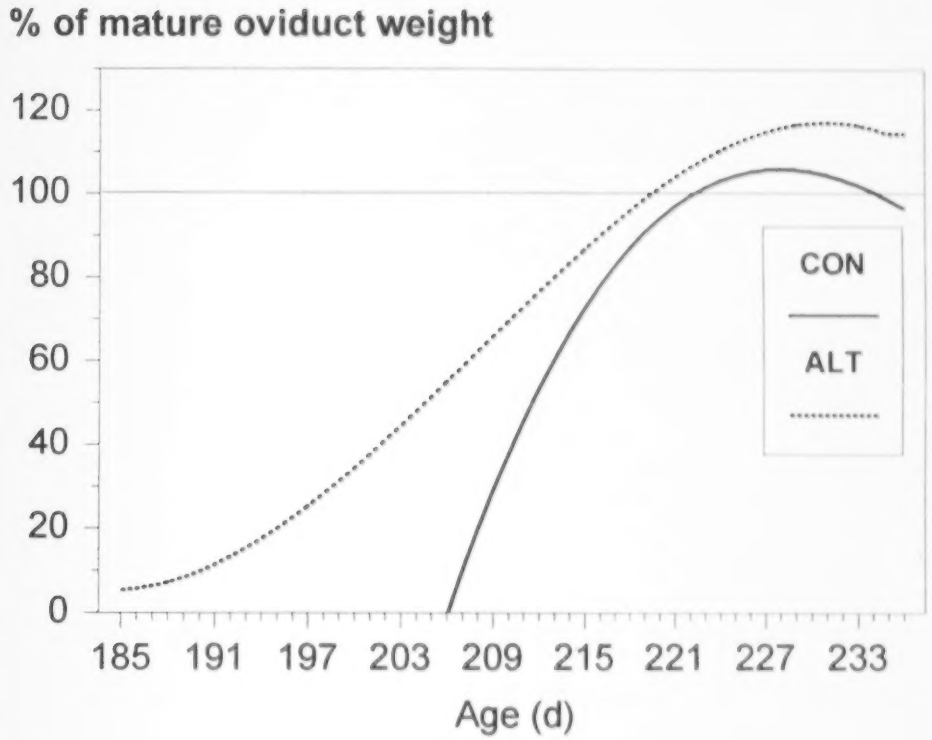

FIGURE III-12. Predicted values of oviduct weight as a percentage of mature organ weight in CON and ALT turkeys

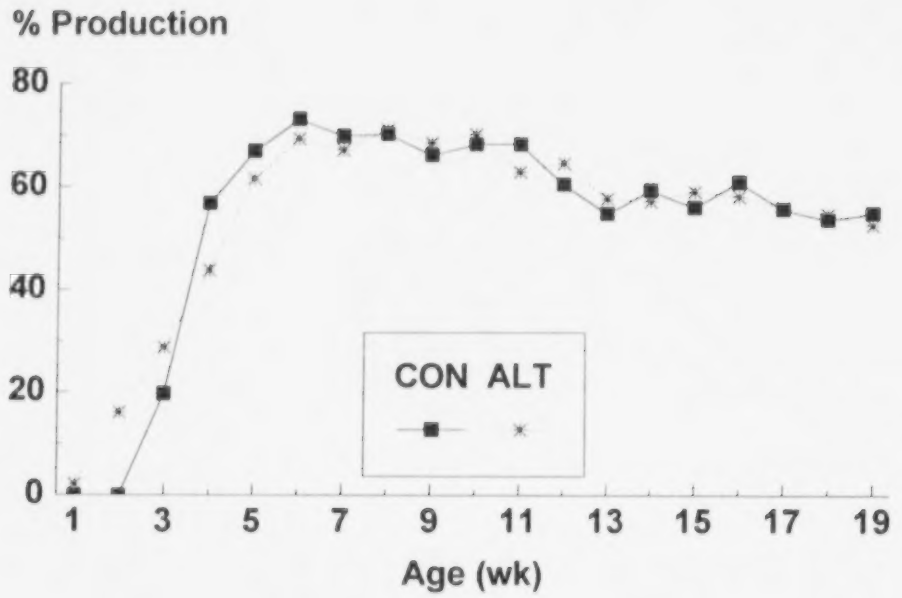

FIGURE III-13. Egg production of CON and ALT turkeys for 20 wk

IV. GENERAL DISCUSSION AND CONCLUSIONS

A clearer understanding is necessary of the reproductive development of different lines of female turkeys in order to develop management strategies that address the specific needs of these lines. The timing of photostimulation programs and the manner in which they are employed can affect reproductive development and subsequent egg production.

Selection for growth traits has resulted in increased numbers of large yellow follicles on the turkey ovary (Nestor, 1971). Reproductive losses such as internal ovulation, multiple ovulation and multiple yolked eggs increase as the number of large follicles increases. Male line breeder hens are the least reproductively fit hen in poultry production. Generally, egg production of male line hens is about half that of female lines. Unlike broiler breeders, turkeys do not respond successfully to feed restriction programs designed to limit BW and improve settable egg production (Hocking *et al.*, 1992; Renema *et al.*, 1994).

Improvements in egg production may be possible through the employment of new management plans. However, different lines of turkeys respond differently to various management strategies such as feed restriction (Hocking, *et al.*, 1992). This is likely due to differences in reproductive development between lines. Male line hens ovulated on average, three times before their first oviposition. Unreconciled ovulations were correlated to internal ovulations which were due to asynchronous development of the ovary and oviduct. As compared to the female line, the ovary of the male line reached its sexually mature weight 3 d before the oviduct did. This 3 d discrepancy corresponds to the three unreconciled ovulations that occur before first oviposition. Photostimulation programs that involve gradual increases in daylength may be beneficial in synchronizing reproductive organ development.

Alteration of present day conventional light programs may prove useful in management programs for some strains of turkeys. Reproductive tract development of male line pullets occurs at a different rate than that of female line pullets. In the male line ovarian development is accelerated as compared to ovarian development in the female line. As well, male line birds have significantly more unreconciled ovulations early in lay which likely result from asynchronous development of the ovary and oviduct.

Reproductive development of commercial birds under a conventional lighting program more closely resembles that of female line birds than that of male line birds. The ovary of female line birds and commercial birds reach their mature weight later than the oviduct does (3 d and 5 d, respectively), whereas the ovary and oviduct of the male line reached their mature weight on the same day. Commercial birds were used in trial II to investigate the merit of alternate lighting programs that could be utilized by managers of commercial breeder hen. Although the present gradual lighting program did not improve egg production of commercial birds a similar program may possibly have more effect on the reproductive development of male line hens either by slowing ovary development or accelerating oviduct development.

The present gradual lighting program appears to be of no benefit to commercial breeder hen management. Marsden *et al.* (1962) found that turkey pullets can be photostimulated with 11 to 12 hours of light per day, however, the ALT birds demonstrated that all birds may not have obtained other prerequisites to sexual maturity such as bodyweight and body composition, at the time of the 11 to 12 hour photoperiod. Age and BW at sexual maturity were subject to high variability; such lack of uniformity early in the

production cycle adds to the complexity of breeder management.

The ALT birds had significantly smaller first eggs and significantly more small eggs in the first four weeks of production. Leighton and Shoffner (1961) found that early photostimulation resulted in more small eggs. Noll (1989) stated that, generally, the longer the light restriction period before photostimulation, the better the settable egg production. A longer holding period at 6 hours of light befor photostimulation for the ALT program may help to improve settable egg production by delaying the age of sexual maturity and lengthening the light restriction period. This delay may, in turn, reduce the number of small eggs and the number of large yellow follicles on the ovary.

Onset of sexual maturity is affected by many factors including genetics, nutrition, disease, temperature and photoperiod. Of these factors, genetics and photoperiod have the greatest influence on onset of sexual maturity (Morris, 1985). Hocking (1992) and Renema (1995) demonstrated there was little improvement in egg production when using various forms of feed restriction. Since all of these factors play a role it may be beneficial to consider management programs that incorporate new approaches to more than one factor at a time. A program with some form of feed restriction and gradual lighting program may help to reduce follicle numbers and improve synchronous development of the ovary and oviduct. Again, since genetics are largely responsible for the differences in reproductive success of different lines, it may be necessary to develop very different management strategies for each line.

Many other aspects of breeder management must also be considered when developing a new lighting program. A gradual lighting program raises many questions, such as when to

relocate females from brooding conditions to laying facilities, how to photostimulate males for semen production used in artificial insemination and when to begin artificial insemination. Since photoperiod can greatly affect production, breeder companies may have to develop new approaches to many areas of the breeding program.

Turkey breeding companies have created a conundrum where egg production traits are compromised for the sake of increased body size. Further attention needs to be paid towards the reproductive fitness of all lines of turkeys. A decline in the propagation of the species will lead to a corresponding decline in the industry. The balance between the selection for reproductive traits and growth traits may need to be shifted more towards improved poult production. Management programs involving more than one approach to improving reproduction should be designed with the differences between lines in mind. If present trends continue at the same rates, management strategies will likely have little affect on the genetically defined production of turkeys.

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